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(54) Title: USE OF DYE TO DISTINGUISH SALT AND PROTEIN CRYSTALS UNDER MICROCRYSTALLIZATION CONDITIONS

(57) Abstract: An improved method of screening crystal growth conditions is provided wherein molecules are crystallized from solutions containing dyes. These dyes are selectively incorporated or associated with crystals of particular character thereby rendering crystals of particular character colored and improving detection of the dyed crystals. A preferred method involves use of dyes in protein solutions overlayed by oil. Use of oil allows the use of small volumes of solution and facilitates the screening of large numbers of crystallization conditions in arrays using automated devices that dispense appropriate solutions to generate crystallization trials, overlay crystallization trials with an oil, provide appropriate conditions conducive to crystallization and enhance detection of dyed (colored) or undyed (uncolored) crystals that result.

5 **USE OF DYE TO DISTINGUISH SALT AND PROTEIN CRYSTALS UNDER
MICROCRYSTALLIZATION CONDITIONS**

CROSS-REFERENCE TO RELATED APPLICATIONS

10 This application claims the benefit of priority of U.S. Provisional Application No. 60/308,698, filed July 30, 2001, to Provisional Application Serial No. 60/328,958, filed October 12, 2001, and to U.S. application Serial No. 09/543,326, filed April 5, 2000, which claims benefit of U.S. Provisional Application 60/128,018, filed April 6, 1999, each of which are hereby incorporated in their entirety herein by reference.

15

STATEMENT OF GOVERNMENT SUPPORT

This invention was made with government support under NASA Cooperative Agreement No. NCC8-246. The government may have certain rights in the invention.

20

FIELD OF THE INVENTION

This invention relates generally to the method of using detectable agents in crystallization of proteins, wherein the detectable agents are preferentially incorporated 25 in the crystals of proteins or preferentially not incorporated in the crystals of proteins such that protein crystals can be readily distinguished from crystals of other substances which can form under the crystallization conditions, thereby allowing rapid and straightforward characterization of crystals and evaluation of crystallization conditions used to obtain the crystals.

30

SUMMARY OF THE INVENTION

In accordance with the purpose(s) of this invention, as embodied and broadly described herein, this invention relates to a method of using dyes to facilitate the

5 characterization of protein crystals present in volumes of one microliter or less. Specifically, it relates to the crystallization of proteins from protein solutions containing dyes under conditions wherein the proteins which crystallize and the other components of the protein solutions which crystallize can be distinguished from one another on the basis of whether or not they form dyed crystals.

10 In a first aspect, this invention relates to a method for forming a dyed protein crystal including the steps of: (1) providing a protein solution, wherein the protein solution contains at least one dye, which dye is capable of dyeing at least a portion of protein crystals formed from the protein solution; (2) subjecting the protein solution to environmental conditions effective to form protein crystals; and (3) detecting the presence of dyed protein crystals, whereby the presence of the dyed protein crystals indicates the presence of protein crystals.

15 In various preferred embodiments of the first aspect of the invention, the dye
20 can be chosen from the group consisting of methylene blue, methylene green, Izit¹ and crystal violet.

25 In various preferred embodiments of the first aspect of the invention, the protein solution is partitioned from the atmosphere. When the protein solution is partitioned from the atmosphere, the partitioning can be done so as to lower the rate at which transfer of solvent from the protein solution occurs. The protein solution can be partitioned from the atmosphere by overlaying the protein solution with an oil. The overlaying oil can be selected from the group consisting of paraffin oil, silicone oil or a combination thereof, for example, AL's oil¹ (a 1:1 mixture of paraffin and silicone oil).
30 The particular mixture of oil selected can be optimized for the rate at which transfer of solvent from a protein solution occurs when the protein solution is overlayed with a particular mixture of oil. Further, the amount of oil overlaying the protein solution can

¹ Reagent is commercially available from Hampton Research, Inc. (www.hamptonresearch.com)

- 5 be selected so as to optimize the rate of solvent transfer from the protein solution, in particular, from the protein solution to the oil and from the oil to the atmosphere.

In various preferred embodiments of the first aspect of the invention, the protein solution further includes a component selected from the group consisting of salts, buffers, precipitants, crystallization aids and any combination thereof. The component selected can crystallize under the controlled environmental conditions to which the protein solution is subjected, thereby producing component crystals. The conditions under which the component crystallizes, can include the step or process of adding a precipitate solution. The component crystals formed can be undyed component crystals.

In various preferred embodiments of the first aspect of the invention, any crystals formed in the provided protein solution can be detected. If crystals are detected, dyed protein crystals can be distinguished from undyed component crystals.

- 20 The protein crystals and component crystals can be detected by microscopy.

In a second aspect, this invention relates to a method for screening protein crystal growth conditions, including the steps of: (1) providing a set of at least two protein solutions, wherein the protein solutions contain a dye, which is capable of dyeing at least a portion of protein crystals formed from the protein solution and which does not dye a significant portion of component crystals formed from the protein solution; (2) subjecting the protein solutions to predetermined conditions, wherein the environmental conditions to which each member of the set of protein solutions is subjected is not identical to the environmental conditions to which another member of the set is subjected; and (3) detecting the presence or non-presence of dyed protein crystals and/or undyed component crystals, wherein the presence of the dyed protein crystals indicates the formation of protein crystals; and the presence of undyed component crystals indicates formation of component crystals.

5

In various preferred embodiments of the second aspect of the invention, the set of protein solutions consists of greater than 10, 50, 100, 250, 500, 1000, 1500, 2000 or 5000 protein solutions.

10 In various preferred embodiments of the second aspect of the invention, the dye can be chosen from the group consisting of methylene blue, methylene green, Ixit¹ and crystal violet.

15 In various preferred embodiments of the second aspect of the invention, the protein solutions are partitioned from the atmosphere. When the protein solutions are partitioned from the atmosphere, the partitioning can be done so as to lower the rate at which transfer of solvent from the protein solutions occurs. The protein solutions can be partitioned from the atmosphere by overlaying the protein solutions with an oil. The overlaying oil can be selected from the group consisting of paraffin oil, silicone oil or a combination thereof, for example, AL's oil¹ (a 1:1 mixture of paraffin and silicone oil).
20 The particular mixture of oil selected can be optimized for the rate at which transfer of solvent from a protein solution occurs when the protein solution is overlayed with a particular mixture of oil. Further, the amount of oil overlaying the protein solution can be selected so as to optimize the rate of solvent transfer from the protein solution, in
25 particular, from the protein solution to the oil and from the oil to the atmosphere.

30 In various preferred embodiments of the second aspect of the invention, the protein solutions further include a component selected from the group consisting of salts, buffers, precipitants, crystallization aids and any combination thereof. The component selected can crystallize under the controlled environmental conditions to which the protein solution is subjected, thereby producing component crystals. The conditions under which the component crystallizes, can include the step or process of

- 5 adding a precipitate solution. The component crystals formed can be undyed component crystals.

In various preferred embodiments of the second aspect of the invention, any crystals formed in the provided protein solutions can be detected. If crystals are
10 detected, dyed protein crystals can be distinguished from undyed component crystals. The protein crystals and component crystals can be detected by microscopy.

In various preferred embodiments of the second aspect of the invention, the detection of dyed protein crystals indicates a combination of environmental conditions
15 to promote crystal growth of a protein in the provide protein solutions. When dyed proteins are detected, the dyed protein crystals can be evaluated in respect to protein crystal quality. Evaluation of protein crystal quality can include consideration of criteria selected from the group consisting of, but not limited to, size of crystals, volume of crystals, intensity of coloration of crystals by dye, color of coloration of
20 crystals by dye, sharpness of crystal edges, and crystal shape.

In various preferred embodiments of the second aspect of the invention, the suitability of crystallization conditions can include evaluation of the protein crystal quality of the crystals obtained by a certain set of environmental conditions.

25 In a third aspect, this invention relates to a method of forming a dyed component crystal including the steps of: (1) providing a component solution, wherein the component solution contains at least one dye, which dye is capable of dyeing at least a portion of component crystals formed from the component solution; (2)
30 subjecting the component solution to environmental conditions effective to form component crystals; and (3) detecting the presence of dyed component crystals, whereby the presence of the dyed component crystals indicates the presence of component crystals.

5

In various preferred embodiments of the third aspect of the invention, the component solution is partitioned from the atmosphere. When the component solution is partitioned from the atmosphere, the partitioning can be done so as to lower the rate at which transfer of solvent to or from the component solution occurs. The component 10 solution can be partitioned from the atmosphere by overlaying the component solution with an oil. The overlaying oil can be selected from the group consisting of paraffin oil, silicone oil or a combination thereof, for example, AL's oil¹ (a 1:1 mixture of paraffin and silicone oil). The particular mixture of oil selected can be optimized for the rate at which transfer of solvent to or from the component solution occurs when the 15 component solution is overlayed with a particular mixture of oil. Further, the amount of oil overlaying the component solution can be selected so as to optimize the rate of solvent transfer to or from the component solution, in particular, from the component solution to the oil, or vice versa, and from the oil to the atmosphere, or vice versa.

20 In various preferred embodiments of the third aspect of the invention, the component solution further includes a protein. The protein selected can crystallize under the controlled environmental conditions to which the component solution is subjected, thereby producing protein crystals. The conditions under which the protein crystallizes, can include the step or process of adding a precipitate solution. The 25 protein crystals formed can be dyed protein crystals.

30 In various preferred embodiments of the third aspect of the invention, any crystals formed in the provided component solution can be detected. If crystals are detected, protein crystals can be distinguished from component crystals on the basis that the protein crystals are undyed protein crystals and the component crystals are dyed component crystals. The protein crystals and component crystals can be detected by microscopy.

5 In a fourth aspect, this invention relates to a method for screening protein
crystal growth conditions including the steps of: (1) providing a set of at least two
protein solutions, wherein the protein solutions contain a dye, which is capable of
dyeing at least a portion of component crystals formed from the protein solution and
which does not dye a significant portion of protein crystals formed from the protein
10 solution; (2) subjecting the protein solutions to predetermined conditions, wherein the
environmental conditions to which each member of the set of protein solutions is
subjected is not identical to the environmental conditions to which another member of
the set is subjected; and (3) detecting the presence or non-presence of undyed protein
15 crystals and/or dyed component crystals. The presence of the undyed protein crystals
can indicate the formation of protein crystals and the presence of the dyed component
crystals can indicate formation of component crystals.

20 In various preferred embodiments of the fourth aspect of the invention, the set
of protein solutions consists of greater than 10, 50, 100, 250, 500, 1000, 1500, 2000 or
5000 protein solutions.

25 In various preferred embodiments of the fourth aspect of the invention, the
protein solutions are partitioned from the atmosphere. When the protein solutions are
partitioned from the atmosphere, the partitioning can be done so as to lower the rate at
which transfer of solvent from the protein solutions occurs. The protein solutions can
be partitioned from the atmosphere by overlaying the protein solutions with an oil. The
overlaying oil can be selected from the group consisting of paraffin oil, silicone oil or a
combination thereof, for example, AL's oil¹ (a 1:1 mixture of paraffin and silicone oil).
The particular mixture of oil selected can be optimized for the rate at which transfer of
30 solvent from a protein solution occurs when the protein solution is overlayed with a
particular mixture of oil. Further, the amount of oil overlaying the protein solution can
be selected so as to optimize the rate of solvent transfer from the protein solution, in
particular, from the protein solution to the oil and from the oil to the atmosphere. The

5 overlaying oil used, or the amount of overlaying oil used, to partition any single protein solution from the atmosphere can be the same or can be different than the overlaying oil used to partition any other protein solution from the atmosphere.

In various preferred embodiments of the fourth aspect of the invention, the
10 protein solutions can further include a component selected from the group consisting of salts, buffers, precipitants, crystallization aids and any combination thereof. The component selected can crystallize under the controlled environmental conditions to which the protein solution is subjected, thereby producing component crystals. The conditions under which the component crystallizes, can include the step or process of
15 adding a precipitate solution. The component crystals formed can be dyed component crystals.

In various preferred embodiments of the fourth aspect of the invention, crystals formed in the provided protein solutions can be detected. If crystals are detected,
20 protein crystals can be distinguished from component crystals on the basis that the protein crystals are undyed protein crystals and the component crystals are dyed component crystals. The protein crystals and component crystals can be detected by microscopy.

25 In various preferred embodiments of the fourth aspect of the invention, the detection of undyed protein crystals indicates a combination of environmental conditions to promote crystal growth of a protein in the provided protein solutions. When undyed proteins are detected, the undyed protein crystals can be evaluated in respect to protein crystal quality. Evaluation of protein crystal quality can include
30 consideration of criteria selected from the group consisting of, but not limited to, size of crystals, volume of crystals, intensity of coloration of crystals by dye, color of coloration of crystals by dye, sharpness of crystal edges, and crystal shape.

5 In various preferred embodiments of the fourth aspect of the invention, the method of screening the suitability of crystallization conditions can include an evaluation of the characteristics, numbers or types of component crystals formed.

10 Additional advantages of the invention will be set forth in part in the description, which follows, and in part will be obvious from the description, or can be learned by practice of the invention. The advantages of the invention will be realized and attained by means of the elements and combinations particularly pointed out in the appended claims. It is to be understood that both the foregoing general description and the following detailed description are exemplary and explanatory only and are not 15 restrictive of the invention, as claimed.

For instance, one advantage provided by one aspect of the invention is that the use of the dye to distinguish between salt and protein crystals allows rapid screening of crystals formed in volumes of less than or equal to approximately one microliter to 20 distinguish between those formed of salt and those formed of protein. The methods known to the art at this time that are used to distinguish between crystals of salt and crystals of protein are not able to achieve this result. The methods used now: (1) the “crush test” where an investigator feels and listens for the sound of salt cracking; (2) bombardment of a crystal by x-rays and subsequent diffraction pattern analysis; and (3) 25 addition of dye after a crystal has been grown and observation of staining; each require a crystal of suitable size (0.3 mm x 0.3 mm x 0.3 mm). Crystals grown from volumes of solution less than or equal to approximately one microliter are too small for these classical methods of analysis. The salt and protein crystals formed are too small to crush or to manipulate effectively for x-ray bombardment. Also, because the volumes 30 in which the crystals are formed are so small, addition of any feasibly manipulated volume of dye solution has significant effects on the composition of the solution containing the crystals and, therefore, significant effects on the crystals therein. Furthermore, as use of such small volumes requires that the crystals be grown in

5 solutions partitioned from the atmosphere, generally by an overlaying oil, it is extremely difficult to add a dye reagent to protein solutions containing crystals. Inclusion of protein solutions prior to crystal growth provides an extremely efficient and simple method to screen for protein crystals in volumes of less than one microliter. Further, this method reduces the time, cost, and skill labor requirements for screening
10 procedures as well as lending itself to forms of automated screening, including for example, methods of automated screening described in U.S. application Serial No. 09/543,326 incorporated herein by reference.

BRIEF DESCRIPTION OF THE DRAWINGS

15 Figure 1 depicts micrograph images of crystallization trials. (Fig. 1A) Izit under oil. (Fig. 1B) NaCl under oil. (Fig. 1C) NaCl + dye under oil. (Fig. 1D) Lysozyme under oil. (Fig. 1E) Lysozyme + dye under oil. (Fig. 1F) Thaumatin under oil. (Fig. 1G) Thaumatin + dye under oil. (Fig. 1H) Catalase under oil. (Fig. 1I) Catalase + dye under oil. (Fig. 1J) Trypsin under oil. (Fig. 1K) Trypsin + dye under oil using CS15. (Fig. 1L) Trypsin + dye under oil using CS16. In each trial, the oil was AL's oil, 50:50 mixture of paraffin oil and silicone oil and the dye was Izit.

25 Figure 2 depicts a lysozyme crystal. This dyed protein crystal, at the lower left quadrant of the well, was grown in the presence of Izit and has incorporated blue dye.

30 Figure 3 depicts a pepsin crystal. This dyed protein crystal was grown in the presence of Izit and has incorporated blue dye.

30 Figure 4 depicts a β -lactoglobulin crystal. This dyed protein crystal was grown in the presence of Izit and has incorporated blue dye.

Figure 5 depicts micrograph images of additional crystallization trials. Figs. 5A-5D depict trials conducted using Izit w/o any added protein under various screening

5 conditions. 5E-5F depict trials with added β -lactoglobulin. Figures 5G-5I depict trials with added myristol transferase. Figure 5J depicts trials with added pepsin. Figures 5K and 5L depict trials with protein Renac2. Figures 5M and 5N depict trials with protein ROB1. Figure 5O depicts a trial with protein B10.

10

DESCRIPTION OF THE PREFERRED EMBODIMENTS

15 The present invention may be understood more readily by reference to the following detailed description of preferred embodiments of the invention and the Examples included therein and to the Figures and their previous and following description.

20 Before the present compounds, compositions, articles, devices, and/or methods are disclosed and described, it is to be understood that this invention is not limited to specific methods of using dye to distinguish between crystals of interest and crystals of other character, specific dyes, to specific methods of detecting dyed crystals or to particular uses of the method disclosed herein, as such may, of course, vary. It is also to be understood that the terminology used herein is for the purpose of describing 25 particular embodiments only and is not intended to be limiting.

30 As used in the specification and the appended claims, the singular forms "a," "an" and "the" include plural referents unless the context clearly dictates otherwise. Thus, for example, reference to "a dye" includes mixtures of dyes, reference to "a component" includes mixtures of two or more such components, and the like.

Ranges may be expressed herein as from "about" one particular value, and/or to "about" another particular value. When such a range is expressed, another embodiment

5 includes from the one particular value and/or to the other particular value. Similarly, when values are expressed as approximations, by use of the antecedent "about," it will be understood that the particular value forms another embodiment. It will be further understood that the endpoints of each of the ranges are significant both in relation to the other endpoint, and independently of the other endpoint.

10

In this specification and in the claims, which follow, reference will be made to a number of terms, which shall be defined to have the following meanings:

15 "Optional" or "optionally" means that the subsequently described event or circumstance may or may not occur, and that the description includes instances where said event or circumstance occurs and instances where it does not. For example, the phrase "solution optionally containing precipitate" means that the solution may or may not contain precipitate and that the description includes both a solution without precipitate and a solution with a precipitate.

20

25 "Detectable," as used herein, means that the presence or absence of the molecule or species so described can be determined. Alternatively, "detectable," as used herein, means that the presence or absence of a certain property or characteristic of a molecule or species so described can be determined. For example, a visually detectable characteristic or property of a species or object, such as a crystal, includes, but is not limited to, the intensity, shade and hue of the species or object.

30 "Dye," as used herein, means an agent which renders another molecule or species detectable by its action on or association with the other molecule or species. Generally, a dye will refer to a visually detectable small molecule, which interacts with, i.e. stains or colors, another molecule. However, dye, as used herein, may also mean an agent that acts on another molecule to render it detectable. Dye, as used herein, may

5 also mean an agent, which absorbs or emits electromagnetic radiation outside of the visible spectrum, e.g., electromagnetic radiation within the ultraviolet spectrum.

“Environment” or “environmental conditions,” as used herein, means the sum total of all the conditions and elements that make up the surroundings and influence the 10 development of any species subject to the environment. The environmental conditions of a protein in solution can be defined in part by description of a limited number of conditions and elements, including but not limited to the identity and abundance of atoms or molecules in solution, including but not limited to solvents, solutes and precipitates; other conditions such as but not limited to pH, temperature and pressure; 15 and the magnitude and orientation of other forces, including but not limited to gravitational forces, magnetic forces and electrostatic forces.

It will be recognized by one of skill in the art that individual substitutions, deletions or additions which alter, add or delete a single amino acid or a small 20 percentage of amino acids (typically less than 5%, more typically less than 1%) in an encoded sequence are conservatively modified variations where the alterations result in the substitution of an amino acid with a chemically similar amino acid. Conservative substitution tables providing functionally similar amino acids are well known in the art. The following six groups each contain amino acids that are conservative substitutions 25 for one another:

- 1) Alanine (A), Serine (S), Threonine (T);
- 2) Aspartic acid (D), Glutamic acid (E);
- 3) Asparagine (N), Glutamine (Q);
- 4) Arginine (R), Lysine (K);
- 30 5) Isoleucine (I), Leucine (L), Methionine (M), Valine (V); and 6) Phenylalanine (F), Tyrosine (Y), Tryptophan (W).

5 Further, it will be recognized by one of skill in the art that two polynucleotides or polypeptides are said to be "identical" if the sequence of nucleotides or amino acid residues in the two sequences is the same when aligned for maximum correspondence. Optimal alignment of sequences for comparison may be conducted by the local homology algorithm of Smith and Waterman *Adv. Appl. Math.* 2: 482 (1981), by the
10 homology alignment algorithm of Needleman and Wunsch, *J. Mol. Biol.* 48: 443 (1970), by the search for similarity method of Pearson and Lipman, *Proc. Natl. Acad. Sci. U.S.A.* 85: 2444 (1988), by computerized implementations of these algorithms (GAP, BESTFIT, FASTA, and TFASTA in the Wisconsin Genetics Software Package, Genetics Computer Group, 575 Science Dr., Madison, WI), or by inspection.

15 The dye(s) used in the practice of the invention may have no effect on the crystallization of a protein contained in the solution. While not being bound by theory, it is contemplated that the nature of the interaction between the selected dyes and protein crystals is such that it has no effect on the structure, stability or growth
20 characteristics of the protein crystals of interest.

The dye(s) used in the practice of the invention may have a negligible effect on the crystallization of proteins contained in the solution. For example, protein crystals formed in the presence of the dye may be functionally equivalent in respect to their use
25 to determine the structure of the crystallized protein, even though the protein crystals grown in the presence of the dye can be distinguished from the protein crystals grown in the absence of the dye on the basis of criteria that can be used to evaluate protein crystal quality, including the size of crystals, volume of crystals, sharpness of crystal edges and crystal shape.

30 The dye(s) used in the practice of the invention may have a significant effect on the crystallization of proteins contained in the solution. For example, the protein crystals' growth may be significantly slower when the protein solution contains the dye

5 or the protein crystals' growth may be significantly faster when the protein solution
contains the dye. Significant differences in the growth rate of protein crystals are those
greater than 5, 10, 15, 25, 50, 75, 100, 500 or 1000 fold different. Also, the quality of
the crystals may be significantly different, as measured by the criteria for determining a
protein crystal's quality, for example, size of crystals, volume of crystals, intensity of
10 coloration of crystals by dye, color of coloration of crystals by dye, sharpness of crystal
edges, and crystal shape.

It will be recognized that under some conditions, for example, when using Izit
dye under high salt conditions and at low pH, colored dye crystals can be formed in the
15 absence of protein. It will also be recognized that under some conditions, certain buffer
components or salts can crystal with the dyes used to form colored crystals. Formation
of such colored dye-only or colored component crystals can be detected by screening
for the formation of colored crystals in the absence of any added protein or biomolecule
of interest. Detection of the presence or absence of such colored crystals under such
20 conditions can be used by one of skill in the art to evaluate the authenticity of colored
crystals formed under such conditions when protein or the biomolecule of interest is
present.

Screening protein crystal growth conditions, as is described herein, refers
25 broadly to the process of providing at least two protein solutions and subjecting them to
different conditions and then determining whether or not the conditions allow for the
crystallization of proteins included in the protein solution. The protein solutions, unless
otherwise indicated, contain the same protein species, which is the protein of interest.
When the protein solutions contain the same protein of interest, the environmental
30 conditions that a given protein solution is subjected to can differ. The protein solutions
can also contain different protein species. When the protein species contained in the
different protein solutions differ, the protein species that differ may be either the
protein of interest and/or other proteins. The protein of interest, as will be recognized

5 by those of skill in the art, is the protein for which the evaluation of protein crystallization conditions is intended. In other words, if an investigator is seeking to establish suitable conditions for the crystallization of protein X, then protein X is the protein of interest.

10 The volume of a protein solution used in the method of forming dyed or undyed protein crystals or in screening protein crystallization conditions, as is described herein, can be greater than 1, 5, 10, 25, 50, 75, 100, 150, 200, 250, 300, 400, 500, 600, 700, 800 or 900 pico-, nano-, or micro-liters. The volume of a protein solution used in the method of forming dyed or undyed protein crystals or in screening protein
15 crystallization conditions, as is described herein, can be less than 5, 10, 25, 50, 75, 100, 150, 200, 250, 300, 400, 500, 600, 700, 800, 900, or 1000 milli-, nano- or pico-liters.

“Partitioned,” as used herein, refers to the segregation of the protein solution from the atmosphere such that the transfer of at least one species present in the solution from the solution to the atmosphere occurs at a lower rate than when the protein solution is not partitioned from the atmosphere. For example, segregation of the protein solution from the atmosphere by the interposition of a semipermeable membrane, which allows the passage of certain solvent molecules, but not others,
25 would partition the protein solution from the atmosphere. When the protein solution is partitioned from the atmosphere, the partitioning may be done so as to lower the rate at which transfer of solvent from the protein solution occurs. The protein solution may be partitioned from the atmosphere by overlaying the protein solution with an oil. The overlaying oil may be selected from the group consisting of paraffin oil, silicone oil or
30 a combination thereof, for example, AL's oil¹ (a 1:1 mixture of paraffin and silicone oil). The particular overlaying oil selected may be optimized for the rate at which transfer of solvent from a protein solution occurs when the protein solution is overlayed with a particular mixture of oil. Paraffin oil is more restrictive to evaporation of water

5 from the overlayed protein solution than either silicone oil or mixtures containing paraffin oil and silicone oil. Mixtures of the two oils can be used where the rate of evaporation to be allowed falls between the rate allowed when 100% paraffin oil is used and when 100% silicone oil is used. Mixtures of the two oils having higher paraffin oil/silicone oil ratios are more restrictive to transfer of water molecules than
10 those mixtures of oil having lower paraffin oil/silicone oil ratios. In mixtures of the two oils, the %(v/v) of either of the two oils, either the paraffin oil or the silicone oil, can be 5, 10, 15, 20, 25, 30, 35, 40, 45, 50, 55, 60, 65, 70, 75, 80, 85, 90 or 95%.

15 The practice of protein crystallization to provide crystals suitable for x-ray diffraction and/or other methods of analysis is often hampered by the difficulty in obtaining crystals of sufficient size and quality for analysis. Thus, the most powerful technique currently available for studying the structure of large molecules can often not be applied to molecules for which there is a need for greater understanding to solve pressing questions relating to the health and welfare of humankind. While the barrier
20 of insufficient crystal quality can often be breached with the application of sufficient resources, the elucidation of the conditions required to produce suitable crystals for x-ray analysis is a significant undertaking. The process for determining suitable conditions generally requires large amounts of both highly skilled labor and highly purified protein.

25

The application and use of the invention greatly decreases both the quantity of labor and protein required to screen potential crystallization conditions to obtain effective crystallization conditions to provide the suitable high quality crystals required for x-ray crystallography of biomolecules for the use in structure based drug design and
30 the attendant benefits thereof.

The significance of the improvement provided by the invention can be appreciated better in light of what is provided by other state-of-the-art practices

5 relating to x-ray crystallographic analysis. In particular, the current automated processes, the availability of intense x-radiation from synchrotron sources and improvements in calculating phases, either from molecular replacement or multiple anomalous dispersion (MAD) strategies, all appear able to handle large numbers of crystallized proteins for structure determination. However, none of these
10 aforementioned processes provide the information necessary, or the means, for identifying the proper environmental conditions to form crystals of molecules for growth, diffraction and/or analysis.

15 The method of the present invention produces a significant aid in determining the conditions suitable for crystallizing proteins, thereby greatly facilitating the production of suitable protein crystals for structural determination without the excessive expenditure of limited resources.

20 In particular, the presently disclosed method can facilitate a great reduction in the quantity of protein needed for the screening of large numbers of crystallization conditions and the time required to analyze the outcome of each crystallization condition trial. It does so by allowing rapid discrimination between crystals of protein and crystals of other components present in a crystallization trial in very small volumes. Furthermore, the ease in discrimination between protein crystals of interest and crystals 25 of other materials (e.g., salt, buffer, precipitants) is of particular usefulness when the presently disclosed use of dye to distinguish between protein and salt crystals is applied to pico, nano or meso scale crystallization trials performed in a microarray or other micro-device.

30 In accomplishing the presently disclosed method, the crystallization trials, or necessary parts thereof, can be automated. As the method used to characterize the nature of crystals present does not require physical contact between the crystal of interest and a probe or other such element, as is required for testing of crystals using

5 conventional means, the method is more amenable to automation than conventional methods now used to determine that a crystal is a protein crystal. Embodiments of the method that are automated are contemplated and provide for the preparation and/or rapid analysis of many samples in high throughput applications.

10 Automated systems to form solutions for preparing crystallization trials, to conduct trials and to monitor the resulting crystallizations, can include any of those features and aspects as described in U.S. provisional application 60/128,018 and U.S. utility application 09/543,326 both of which are incorporated herein by reference in their entirety. However, the automated systems or components thereof need not include
15 all features described in the previous applications. Minimally, a fully automated system need only include an automated dispensing system to deliver crystallization trial volumes to receptacles, a capability to provide an environment in which crystals can form under at least some conditions, and an ability to detect the presence or absence of formed crystals. The present invention includes the use of dye to facilitate the
20 detection of crystals. Thus, devices of the present invention adapted for automated screening do provide solutions containing the appropriate selected dye and do provide an environment that allows detection of dyed crystals. In one aspect, provision of that environment is effected by use of wells having clear sides or a clear path for optical detection. As will be recognized by one of skill in the art, such an environment need
25 not provide such a clear optical path provided other means for detecting the presence of the dyed crystals is provided. Examples of such other means include, but are not limited to, detectors present within the wells, devices for removal of crystals from wells, and detectors as are known in the art that do not rely upon the presence of a clear optical path, but instead rely on other physical or chemical properties.

30

In particularly useful embodiments contemplated, the method can include use of an automated system that dispenses the appropriate solutions to form a crystallization trial that includes the presence of a dye useful in the practice of the invention and

5 overlays the crystallization trial with an oil. Such an automated solution can include a microarray for crystallization trials, an automated dispensing mechanism for dispensing the solutions, an automated dispensing mechanism for dispensing the overlaying oil, and an automated means for detecting crystal growth.

10 In particularly useful embodiments contemplated, the method can encompass use of an analysis station that detects the color of crystals in samples that are provided to the analysis station in an automated fashion. As will be recognized by those of ordinary skill in the art, detection of crystal color can include the monitoring and detection of selected portions of the spectra of electromagnetic radiation that are 15 absorbed, reflected or transmitted by a crystal, whereby detection of said selected portions of the spectra are indicative of a color.

Such automated methods can further include the sorting of crystals in regard to their determined characteristics. Such sorting can be of a physical nature (i.e., the 20 samples containing the crystals are segregated according to the nature of crystals contained therein) or can be of an informational nature (i.e., the identity of samples containing crystals of a particular nature and/or the location of crystals of a particular nature within a sample are recorded).

25 Such automated methods can also include determination of the number of crystals or objects of specified character or identity within a given sample, set of samples or other groups. Further, the number and identity relating to obtained crystals can also be used as a descriptor of conditions used to obtain crystals. For example, the total number of biomolecule crystals obtained and/or the fraction of crystals obtained 30 that are biomolecule crystals can be used to describe results obtained using specific sets of conditions that can be used to form crystals of a specified character.

5 The automated method can monitor samples or crystals within samples. The
automated method can operate in response to a predetermined program. The
predetermined program can include input or instructions from the user. Input or
instructions can be provided prior to the screening process or can be provided during
the screening process either in response to queries generated by the predetermined
10 program or by the initiative of the user.

Data obtained from the method can include images and data sets representing
images or data derived from both images or selected portions of images. Images can be
acquired automatically, with user action or with a combination of both automated and
15 non-automated processes. Particular details regarding details of data analysis and
determination of whether a biomolecule or a nonbiomolecule (i.e., a protein crystal or a
salt crystal) will, of course, vary depending on the characteristics of the crystallization
conditions and the dye being used. Optimization of such particular details are well
understood by those of skill in the art and would be recognized not to rise to the level of
20 undue experimentation.

The following examples are put forth so as to provide those of ordinary skill in
the art with a complete disclosure and description of how the compounds,
compositions, articles, devices and/or methods claimed herein are made and evaluated,
25 and are intended to be purely exemplary of the invention and are not intended to limit
the scope of what the inventors regard as their invention. Efforts have been made to
ensure accuracy with respect to numbers (e.g., amounts, temperature, etc.), but some
errors and deviations should be accounted for. Unless indicated otherwise, parts are
parts by weight, temperature is in °C or is at ambient temperature, and pressure is at or
30 near atmospheric.

5 **EXAMPLE ONE**

Crystallization of Selected Proteins from Protein Solutions containing Izit.

Introduction

The ability to distinguish between salt and protein crystals has been a problem solved by conventional x-ray crystallographers in a variety of methods. Those methods 10 include the "crush" test whereby a crystal is crushed and determined to be salt if it makes a cracking sound. A second method involves placing the crystal in a x-ray beam and looking for diffraction resolution. A third method includes the addition of a dye composed of methylene blue under the commercial name of Izit to the volume containing a crystal. Theoretically, a crystal of protein contains large channels of 15 solvent and will readily uptake the dye, while a crystal of salt is so well packed that the dye will not be taken up into the salt crystal. Each of these methods has their pros and cons. The crush test con is readily apparent, crush your protein crystal and you're back to the starting point. Mounting crystals and shooting to ascertain their ability to diffract takes a significant amounts of time and effort. The addition of dye to stain protein 20 crystals is clearly useful, even if not 100 % accurate. However, the addition of dye to stain crystals resulting from a crystallization trial cannot be easily used under certain circumstances, particularly those circumstances where small volumes are required.

The process for high through put screening for protein crystallization conditions 25 has been miniaturized which thus improves efficiency, but results in the growth of unmanageably small crystals. The crystals are too small for either the crush test or x-ray analysis, due to difficulty in handling, indeed, even addition of dye to the small volumes and to the small crystals is difficult. A simple solution to the problem, the scaling up of various trials to determine if crystals were salt or protein, results in the 30 creation of a bottleneck for high flux structure determination projects, thus negating one of the primary advantages sought in the miniaturization of the screening process.

5 Herein, an alternative method of discriminating between protein and salt
crystals is disclosed. As described in this example for the purpose of illustration, it
includes the addition of a blue dye to crystallization trials of approximately one
microliter or lower volumes under paraffin oil as an aid to the detection and the
characterization of protein crystals and/or the characterization of crystals as protein
10 crystals.

Materials and Methods:

The proteins screened in this example were: hen egg white lysozyme (Boehringer Mannheim, 1243004), 30 mg/ml in 0.1 M sodium acetate (pH 4.7);
15 thaumatin (Sigma, T7638), 30 mg /ml in 100 mM Tris-HCl (pH 6.5); bovine catalase (Sigma, C40), 30 mg / ml in 50 mM HEPES (pH 7.0); cellulase from *T. viride* (Sigma, C40), 40 mg / ml in 100 mM Tris-HCl (pH 8.5); bovine trypsin (Sigma, T8253), 60 mg / ml in 25 mM HEPES (pH 7.0), 10 mM CaCl₂, 10 mg / ml benzamidin HCl; porcine pepsin (Sigma, P6887), 60 mg / ml in 100 mM cacodylate buffer (pH 6.5), 0.2 M Ca acetate; equine serum albumin (Sigma, A3434), 50 mg / ml in 50 mM sodium acetate (pH 5.5); *Bacillus licheniformis* α -amylase (Sigma, A4551), 25 mg / ml in 50 mM cacodylate buffer (pH 6.75), 2 mM CaCl₂; Barley β -amylase (Sigma, A7130), 8 mg / ml in 100 mM HEPES (pH 7.5); bovine β -lactoglobulin (Sigma, L3908), 10 mg/ml in 100 mM Tris-HCL (pH 6.5). Precipitants were prepared using reagents from Sigma or
20 Hampton Research. Paraffin oil and Izit were purchased from Hampton Research. Izit is a commercial preparation of methylene blue dye, a planar aromatic dye with a molecular weight of 319 daltons. Crystallization trials were performed in Labsystems 384 clinical plates under 40 μ l of paraffin oil. Crystallization buffers used for:
25 lysozyme (100 mM sodium acetate (pH 4.7), 7 % NaCl); thaumatin (1.5 M sodium potassium tartrate); catalase (Crystal Screen 36 (Hampton Research), 100 mM Tris (pH 8.5), 8 % PEG8000)); cellulase (1.4 M ammonium sulfate); trypsin (Crystal Screens 4, 15, 16, 20, 28,30, 31 (Hampton Research), namely for, (4) 0.1 M Tris-HCl (pH 8.5), 2.0 M ammonium sulfate; (15) 0.2 M ammonium sulfate, 0.1 M sodium cacodylate (pH

5 6.5), 30 % PEG8000; (16) 0.1 M HEPES (pH7.5), 1.5 M lithium sulfate monohydrate;
 (20) 0.2 M ammonium sulfate, 0.1 M sodium acetate trihydrate (pH 4.6), 25 %
 PEG4000; (28) 0.2 M sodium acetate trihydrate, 0.1 M sodium cacodylate (pH 6.5), 30
 % PEG8000; (30) 0.2 M ammonium sulfate, 30 % PEG8000;(31) 0.2 M ammonium
 sulfate 30% PEG4000; pepsin, 18 % PEG8000; equine serum albumin, 2.0 M
10 ammonium sulfate; α -amylase, 1 N NaOH; β -amylase, 0.17 M ammonium sulfate, 15
 %PEG8000; β -lactoglobulin, 2.0 M ammonium sulfate.

15 Crystallization trials were initiated by mixing equal portions of protein and
 precipitant solutions prior to depositing a 0.5 μ l protein solution drop in the bottom of a
 crystallization chamber. Protein solutions were then covered with 40 μ l of paraffin oil.
The crystallization chambers were left unsealed to incubate at 20 °C. Crystal growth
was monitored daily.

Results

20 The dye added to, and present in, the protein solutions of the nanoliter volume
 crystallization trials conducted under oil did not appear to diffuse into the paraffin oil.
The dye did not stain salt crystals formed during the trials, nor did the presence of the
dye interfere with salt crystal formation. As a further control, a 0.5 μ l drop of undiluted
Izit under 40 μ l of paraffin or Al's (Hampton Research) oil was allowed to incubate at
25 20° C. After 72 hours the dye did not appear to have diffused into the surrounding oils.
Even after evaporation of the Al's oil, the blue dye remained in place. As further
controls, four 0.5 μ l samples of saturated NaCl solution were deposited into four
separate containers. In three of these, crystallization trials were initiated with the
addition of Izit in quantities of 1 part per 30 parts solution, 1 part per 60 parts solution,
30 and 1 part per 100 parts solutions. Crystals of NaCl were formed under oil in both the
absence and the presence of Izit. In none of the trials, under any of the dilutions tested,
did the blue dye enter, and thereby color, the salt crystals. As reported, Izit itself will
crystallize under conditions of high salt. When this occurs, the crystallized Izit form

5 distinctive networks of blue fibers or sea urchin crystals. (Note: in Example Three, evidence is presented that suggests that other crystalline forms of Izit or dyed crystals of component(s) can occur. In particular, it is noted that sodium thiocyanate might form dyed crystals under particular conditions.)

10 For most proteins, the addition of dye to the protein samples tested did not interfere with crystal formation, and furthermore, resulted in the production of colored protein crystals, i.e. the dye was taken up by the protein crystals (Table 1; Figure 1). For each test protein, equal volumes of sample and crystallization buffer were mixed. These crystallization samples were either taken as is, "neat," or Izit was added at a ratio
15 of 1:30, 1:60, or 1:100 in respect to the crystallization sample volume. After preparation of the crystallization samples, the samples were deposited into the crystallization chambers as described in the Materials and Methods section. Crystal trial samples were then covered with 40 µl of paraffin oil and the experiments monitored for the formation of protein crystals. Seven out of ten test proteins
20 crystallized in the absence of dye, specifically, lysozyme, thaumatin, cellulase, pepsin, trypsin, equine serum albumin and catalyse crystals formed in the absence of the blue dye. Each of these test proteins also crystallized in the presence of dye, but crystallization of only four definitively resulted in blue crystals, specifically, lysozyme, thaumatin, trypsin and equine serum albumin. Equine serum albumin displayed phase
25 changes in the absence and presence of dye. Crystallization of cellulase resulted in small flat square plates that appeared to display staining intensity, but it was not possible to definitively characterize the cellulase crystals as blue due to the thinness of the resultant crystals and the resulting similarity of the coloration to the background. The color of cellulase crystals was similar to background hence it was not evident if
30 these crystals absorbed the dye. In addition, characterization of the cellulase crystals was further complicated by their small size. The background intensity due to unincorporated dye present in each sample was similar for each protein tested. The amount of dye incorporated into the protein crystals, and therefore the intensity of

5 resulting coloration, depended on the concentration of dye used and the number and size of the crystals (Figure 1). The reason(s) for the inability of catalase and pepsin to form crystals in the presence of IZIT are unknown. It is reasonable to postulate that the failure of catalase and pepsin crystals to form in the presence of IZIT is only isolated to the single set of conditions used in this trial. As evidenced by the results when
10 attempting to crystallize trypsin, alteration of the environmental conditions to which a protein solution is subjected can effect changes in the incorporation of dye into a protein crystal.

The addition of blue dye to micro and even nano crystallization trials under oil,
15 or in a miniaturized crystallization condition screening device, such as a microarray, will provide significant savings in material, time and money. In large part, the savings result from the ability to determine that crystals formed in a miniaturized system, under a specific set of conditions, are protein crystals, without having to replicate the specific set of conditions on a larger scale, thereby negating much of the initial benefit of
20 miniaturization. While this improved method of screening crystallization conditions is by no means a replacement for growing suitable sized crystals for analysis, it offers a significant improvement to the process of determining appropriate conditions to grow the suitable sized crystals required.

25 **EXAMPLE TWO**

Screening Crystallization Conditions for Crystallization of Selected Proteins from Protein Solutions containing IZIT.

Introduction

The blue dye IZIT facilitated the screening of crystallization conditions suitable
30 for producing crystals of lysozyme, pepsin and β -lactoglobulin. The experimental design used in conjunction with the ability to detect nano-scale crystals, facilitated by the use of the dye, allowed 450 different sets of conditions to be screened. This set of trials, performed in duplicate and systematically screening 10 variables, consumed only

5 a few micrograms of protein. Each crystallization variable was represented by several implementations. For example, the variable organic precipitant was represented by five levels: 1, 2-methyl-2,4-pentanediol (MPD); 2, polyethylene glycol 400 (PEG400); 3, PEG2000; 4, PEG4000; and 5, PEG8000. This is in stark contrast to classical approaches normally used in crystallography that use tens of milligrams of protein to
10 screen approximately 24-48 sets of conditions. The ease and economy in which protein crystallization conditions can be screened using these disclosed methods allows a thorough sampling of crystallization parameters for any given protein. This allows an investigator to readily identify conditions optimal for crystallization and can be used to determine conditions suitable for the growth of protein crystals of suitable size and
15 quality for analysis and characterization.

Materials and Methods:

The proteins used as test proteins for this example were: hen egg white lysozyme (Boehringer Mannheim, 1243004), 30 mg/ml in 0.1 M sodium acetate (pH 4.7); porcine pepsin (Sigma, P6887), 60 mg / ml in 100 mM cacodylate buffer (pH 6.5), 20 0.2 M Ca acetate; bovine β -lactoglobulin (Sigma, L3908), 10 mg/ml in 100 mM Tris-HCL (pH 6.5). The concentrations and buffer solutions used for the nano crystallization screen are identical to those used in the 0.5 μ l scale experiments described earlier. Prior to the initiation of the nano crystallization screen IZIT was 25 added to each sample using a dilution of 1 part dye to 19 parts protein (v/v).

Paraffin oil and Izit were purchased from Hampton Research. Nanoliter crystallization screens were initiated by deploying various ratios of protein sample containing blue dye and crystallization buffer (described in Appendix One) into a 30 chamber and then overlaying with 40 μ l of Al's oil. The final volume of the experiments were 80 nl. The ratio of protein to precipitating buffer was either 1: 2, 1:1, or 2:1. The exact composition of each of the 450 recipes used is recorded in the table of screen conditions (Appendix One). The pH of the recipes can be calculated using

5 the Henderson-Hasselback equation. Unless otherwise indicated, the buffer components included in the crystallization trial condition recipes are the base (HEPES and MES). MPD and β -OG are 2-methyl-2,4-pentanediol and N-octyl- β -d-gluocpyranoside. PEG400, PEG2K, PEG4000 and PEG 8K are polyethylene glycols of indicated size/mass as is known to those of skill in the art.

10

The experimental nanoliter crystallization volumes were sealed during the trials. Data were collected four days after the initiation of the experiment and recorded. The results were scored by visual inspection.

15 Crystallization trials were conducted using the precipitant solutions described in Appendix one at the ratios indicated. 450 trial conditions, repeated in duplicate, were tested for each of the proteins. The total volume for each trial protein solution was 80 nanoliters at the beginning of the trial. Each volume of protein solution was overlayed with 40 μ l of Al's oil. The crystallization chambers were sealed and left to incubate at
20 4 °C and 20 °C. Crystal growth was recorded on the fourth day.

Results

Conditions which promoted crystallization for each of the three proteins tested were identified. The numbers and types of crystals formed in the trials can be found in
25 Table 2. For each of the three proteins, i.e., lysozyme, pepsin and β -lactoglobulin, there were 900 total trial results (450 trial screening conditions performed in duplicate). Results for each trial, i.e., each separate volume of protein solution, were analyzed and categorized. These categories include: (1) a clear drop, (2) phase separation, (3) precipitate (regular, granular), (4) microcrystals/precipitate, (5) rosettes or spherulites,
30 (6) needles (one-dimensional growth), (7) plates (two-dimensional growth), (8) small crystals (three-dimensional growth of less than 0.2 mm) and (9) crystals (three-dimensional growth of greater than 0.2 mm). The categories or scores used for the nanoliter crystallization trials were adopted from those suggested by Hampton

5 Research. Scoring of individual experiments to assign each to a category was performed by visual inspection. As the titles of the categories suggest, the results of each experiment were scored based upon presence or absence of detectable species and upon the species' morphology. For example, needle-like crystals are those appear to have one axis that is very long compared to the others, while plates have two axes of
10 approximately equivalent size, each significantly larger than the third. A three dimensional crystal appears to have growth in three dimensions and looks like a brick. For the other categories, precipitate looks like sand, while both phase separations and rosettes look like mixtures of oil and water. The rosettes usually appear to have dense staining in their centers. In some instances, there is greater ambiguity as to the proper
15 categorical assignment. In addition, the total number of trials in which blue crystals formed is also indicated. The number of blue crystals is calculated from visual inspection of categories 6 – 9, i.e., needles, plates, small three dimensional crystals and larger three dimensional crystals. A representative micrograph of blue crystals formed from each of the three proteins screened is shown in Figures 2-4. Specifically: Figure 2
20 shows a blue lysozyme crystal grown in the presence of Izit using screening condition 361; Figure 3 shows a blue pepsin crystal grown in the presence of Izit using screening condition 75; and Figure 4 shows a blue β -lactoglobulin crystal grown in the presence of Izit using screening condition 213.

25 **EXAMPLE THREE**

Screening Crystallization Conditions for Crystallization of Selected Proteins from Protein Solutions containing Izit and Controls.

Methods similar to those described in Example 2 were used to test the method of the invention using additional proteins and conditions. Figure 5 shows micrographs
30 of these trials wherein proteins, buffer, conditions and dye were varied in character and quantity. Trials were conducted as described before and using the noted screening Expt. # [Stock] conditions outlined in Appendix One. In the following example; T1=4 °C, T2=15 °C, and T3=22 °C.

5

Crystallization conditions using Izit dye w/o any added protein were examined. For example, screening conditions 251 (at T3), 254 (at T3), 285 (at T2), 266 (at T3) and 339 (at T3) were conducted. Results from conditions 251, 285, 266, and 339 are shown in Figure 5A, B, C, and D, respectively. Condition 254, results not shown, resulted in no observable precipitation or crystallization. Condition 251 (Figure 5A) also does not result in any observable crystal formation. However, condition 285, which includes acetate buffer at pH 4.5, 42 mM Ammonium Sulfate, 3.7% MPD, 1% glycerol and 2 mM magnesium chloride, and condition 339, which includes acetate buffer at pH 4.5, 460 mM thiocyanate, 0.8% PEG 8000, 0.5% glycerol and 8 mM arginine-HCl, both result in apparent crystals.

Crystallization conditions with various proteins were also examined. Figure 5E and 5F show results from β -lactoglobulin under conditions with phosphate buffer at pH 8 and with PEG 400 (at T1) and with phosphate buffer at pH 6, PEG 8000, 10% glycerol, 0.008M Arg-HCl (at T3), respectively. Figure 5G, 5H, and 5I show results from myristol transferase under conditions 291 (at T3), 197 (at T2) and 259 (at T3), respectively. Figure 5J shows results from pepsin under condition 347 (at T3). Figures 5K and 5L show results from Renac2 under conditions 41 (at T1) and 339 (at T3), respectively. Figures 5M and 5N show results from Rob1 under conditions 212 (at T2) and 337 (at T3), respectively. Figure 5O shows results from B10 in acetate buffer at pH 4.5, with 450 mM thiocyanate, 0.8% PEG 8000, 0.5% glycerol and 8 mM arginine HCl (at T3).

Throughout this application, various publications are referenced. The disclosures of these publications in their entireties are hereby incorporated by reference into this application in order to more fully describe the state of the art to which this invention pertains.

5 It will be apparent to those skilled in the art that various modifications and variations can be made in the present invention without departing from the scope or spirit of the invention. Other embodiments of the invention will be apparent to those skilled in the art from consideration of the specification and practice of the invention disclosed herein. It is intended that the specification and examples be considered as
10 exemplary only, with a true scope and spirit of the invention being indicated by the following claims.

Table 1**Summary of IZIT Crystallization Results**

| Protein | Xt1 | Bxt1 | Bxt1 | Bxt1 | Condition | Min. pH |
|------------------------|-----|------|------|------|-----------|---------|
| Lysozyme | Xt1 | Bxt1 | Bxt1 | Bxt1 | | 4.7 |
| Thaumatin | Xt1 | Bxt1 | Bxt1 | Bxt1 | HR | 6.5 |
| Catalase | Xt1 | - | - | - | CS36 | 8.0 |
| Cellulase | Xt1 | Xt1 | Xt1 | Xt1 | | 8.5 |
| Pepsin | Xt1 | - | - | - | | 6.5 |
| Equine serum albumin | Pc | BPc | BPc | BPc | | 5.5 |
| α -amylase | - | - | - | - | | 7.0 |
| β -amylase | - | - | - | - | | 7.5 |
| β -lactoglobulin | - | - | - | - | | 6.5 |
| Trypsin | Xt1 | Bxt1 | Bxt1 | Bxt1 | CS4 | 7.0 |
| Trypsin | Xt1 | Xt1 | Xt1 | Xt1 | CS15 | 7.0 |
| Trypsin | Xt1 | Bxt1 | Bxt1 | Bxt1 | CS16 | 7.0 |
| Trypsin | Xt1 | Xt1 | Xt1 | Xt1 | CS20 | 7.0 |

| Protocol | Neat | Izit 30 | Izit 60 | Izit 100 | Condition | Final pH |
|----------|------|---------|---------|----------|-----------|----------|
| Trypsin | Xtl | Xtl | Xtl | Xtl | CS28 | 7.0 |
| Trypsin | Xtl | Xtl | Xtl | Xtl | CS30 | 7.0 |
| Trypsin | Xtl | Xtl | Xtl | Xtl | 31 | 7.0 |

5

Xtl = crystal, Bxtl = blue crystal, Pc = phase change, BPc = blue phase change, neat = absence of Izit in crystallization trial. Condition = the crystallization buffer used. CS = crystal screen. HR = Hampton Research web page <http://www.hamptonresearch.com/>.

Table 2A
Lysozyme

10

| Protocol | Fractionality |
|-------------------------|---------------|
| 1 | 795 |
| 2 | 58 |
| 3 | 17 |
| 4 | 3 |
| 5 | 1 |
| 6 | 4 |
| 7 | 1 |
| 8 | 21 |
| Number of blue crystals | 10 |

Table 2B
Pepsin

15

| Protocol | Fractionality |
|----------|---------------|
| 1 | 591 |
| 2 | 24 |
| 3 | 30 |
| 4 | 9 |
| 5 | 0 |
| 6 | 25 |
| 7 | 164 |

| | |
|-------------------------|----|
| 8 | 57 |
| Number of blue crystals | 2 |

5

Table 2C
 β -Lactoglobulin

| Score | Frequency |
|-------------------------|-----------|
| 1 | 807 |
| 2 | 58 |
| 3 | 8 |
| 4 | 13 |
| 5 | 1 |
| 6 | 5 |
| 7 | 7 |
| 8 | 1 |
| Number of blue crystals | 5 |

10

1 Score Definitions

| Score | Score Description |
|-------|--------------------------------|
| 1 | Clear Drop |
| 2 | Phase Separation |
| 3 | Precipitate (Regular Granular) |
| 4 | MicroCrystals / Precipitate |
| 5 | Rosettes or Spherulites |
| 6 | Needles (1D Growth) |
| 7 | Plates (2D Growth) |
| 8 | Crystals (3D Growth < 0.2mm) |
| 9 | Crystals (3D Growth > 0.2mm) |

15

| Code | Expt # | NES [Stock] | HEPE S [0.5M] | Sodium S [0.5M] | Sodium mChloride [2M] | Citric Acid [2M] | Acetic Acid [2M] | Ammo nium Sulfate [2M] | MFD [30%] | Monos odium Phosp hate [2M] | PEG 400 [30%] | PEG 2K [30%] | PEG 8K [30%] | PEG 4000 [30%] | PEG 8K [30%] | CaCl2 [0.2M] | CaCl2 [0.2M] | Arginin e-HCl [0.5M] | Beta OG [0.5M] | Glycer ol [75% w/w] | Total Recipe dispensed | Protein dispensed | | | | | | | |
|------|--------|-------------|---------------|-----------------|-----------------------|------------------|------------------|------------------------|-----------|-----------------------------|---------------|--------------|--------------|----------------|--------------|--------------|--------------|----------------------|----------------|---------------------|------------------------|-------------------|------|------|------|------|------|---|---|
| 1 | 62 | 0 | 9 | 0 | 0 | 0 | 0 | 0 | 40 | 203 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 31 | 41 | 614 | 1000 | 3 | 1 | | | |
| 2 | 62 | 62 | 63 | 0 | 0 | 0 | 0 | 0 | 114 | 0 | 0 | 0 | 0 | 0 | 125 | 0 | 0 | 0 | 0 | 0 | 31 | 0 | 0 | 585 | 1000 | 3 | 1 | | |
| 3 | 62 | 0 | 11 | 48 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 240 | 15 | 0 | 0 | 0 | 0 | 31 | 41 | 552 | 1000 | 3 | 1 | | | |
| 4 | 62 | 0 | 215 | 0 | 75 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 83 | 0 | 0 | 15 | 31 | 0 | 21 | 499 | 1000 | 3 | 1 | | | | |
| 5 | 62 | 0 | 151 | 0 | 0 | 152 | 0 | 0 | 14 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 15 | 0 | 0 | 41 | 566 | 1000 | 3 | 1 | | | | |
| 6 | 62 | 0 | 204 | 0 | 75 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 83 | 0 | 0 | 0 | 0 | 15 | 0 | 31 | 21 | 509 | 1000 | 3 | 1 | | |
| 7 | 62 | 0 | 7 | 121 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 11 | 0 | 0 | 0 | 0 | 31 | 41 | 729 | 1000 | 3 | 1 | |
| 8 | 62 | 0 | 11 | 40 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 196 | 0 | 0 | 0 | 0 | 0 | 31 | 0 | 21 | 641 | 1000 | 3 | 1 | | |
| 9 | 62 | 4 | 115 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 127 | 15 | 0 | 0 | 31 | 0 | 21 | 626 | 1000 | 3 | 1 | | |
| 10 | 62 | 0 | 301 | 0 | 152 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 13 | 0 | 0 | 0 | 0 | 15 | 0 | 31 | 41 | 385 | 1000 | 3 | 1 | | |
| 11 | 62 | 0 | 51 | 0 | 0 | 39 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 194 | 0 | 0 | 0 | 0 | 15 | 0 | 31 | 0 | 608 | 1000 | 3 | 1 | | |
| 12 | 62 | 8 | 0 | 0 | 0 | 149 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 15 | 0 | 0 | 31 | 0 | 0 | 0 | 0 | 0 | | |
| 13 | 62 | 0 | 11 | 182 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 13 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | |
| 14 | 62 | 0 | 62 | 98 | 0 | 0 | 95 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 105 | 0 | 0 | 0 | 0 | 15 | 0 | 31 | 0 | 21 | 694 | 1000 | 3 | 1 | |
| 15 | 62 | 4 | 0 | 62 | 43 | 0 | 0 | 0 | 0 | 182 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 15 | 0 | 31 | 0 | 21 | 573 | 1000 | 3 | 1 | |
| 16 | 62 | 0 | 62 | 39 | 0 | 0 | 0 | 0 | 0 | 48 | 244 | 0 | 0 | 0 | 0 | 16 | 0 | 0 | 0 | 0 | 15 | 0 | 31 | 0 | 21 | 701 | 1000 | 3 | 1 |
| 17 | 62 | 94 | 0 | 0 | 0 | 0 | 0 | 0 | 95 | 0 | 0 | 0 | 0 | 0 | 108 | 0 | 0 | 0 | 0 | 0 | 31 | 0 | 21 | 556 | 1000 | 3 | 1 | | |
| 18 | 62 | 40 | 0 | 0 | 0 | 0 | 0 | 0 | 181 | 16 | 0 | 0 | 0 | 0 | 0 | 16 | 15 | 0 | 0 | 31 | 0 | 21 | 591 | 1000 | 3 | 1 | | | |
| 19 | 62 | 0 | 43 | 0 | 0 | 43 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 106 | 0 | 0 | 0 | 0 | 0 | 31 | 0 | 21 | 670 | 1000 | 3 | 1 | | |
| 20 | 62 | 0 | 62 | 47 | 0 | 0 | 0 | 0 | 0 | 114 | 0 | 0 | 0 | 0 | 0 | 197 | 0 | 0 | 0 | 0 | 15 | 0 | 31 | 0 | 21 | 566 | 1000 | 3 | 1 |
| 21 | 62 | 0 | 7 | 0 | 0 | 0 | 0 | 0 | 183 | 0 | 16 | 0 | 0 | 0 | 0 | 129 | 0 | 0 | 0 | 0 | 15 | 0 | 31 | 0 | 21 | 617 | 1000 | 3 | 1 |
| 22 | 62 | 164 | 0 | 0 | 152 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 14 | 0 | 0 | 0 | 0 | 15 | 0 | 31 | 0 | 21 | 591 | 1000 | 3 | 1 | |
| 23 | 62 | 3 | 0 | 0 | 0 | 96 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 106 | 0 | 0 | 0 | 0 | 15 | 0 | 31 | 0 | 21 | 522 | 1000 | 3 | 1 | |
| 24 | 62 | 0 | 37 | 0 | 0 | 40 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 197 | 0 | 0 | 0 | 0 | 15 | 0 | 31 | 0 | 21 | 661 | 1000 | 3 | 1 | |
| 25 | 62 | 0 | 3 | 40 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 235 | 0 | 0 | 0 | 0 | 15 | 0 | 31 | 0 | 21 | 598 | 1000 | 3 | 1 | |
| 26 | 62 | 0 | 124 | 0 | 0 | 115 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 197 | 0 | 0 | 0 | 0 | 15 | 0 | 31 | 0 | 21 | 611 | 1000 | 3 | 1 | |
| 27 | 62 | 0 | 105 | 96 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 141 | 0 | 0 | 0 | 0 | 15 | 0 | 31 | 0 | 21 | 536 | 1000 | 3 | 1 |
| 28 | 62 | 0 | 7 | 96 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 106 | 0 | 0 | 0 | 0 | 15 | 0 | 31 | 0 | 21 | 590 | 1000 | 3 | 1 | |
| 29 | 62 | 0 | 17 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 106 | 0 | 0 | 0 | 0 | 15 | 0 | 31 | 0 | 21 | 642 | 1000 | 3 | 1 | |
| 30 | 0 | 62 | 4 | 116 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 131 | 0 | 0 | 0 | 0 | 15 | 0 | 31 | 0 | 21 | 672 | 1000 | 3 | 1 | |
| 31 | 0 | 62 | 4 | 0 | 0 | 161 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 15 | 0 | 31 | 0 | 21 | 647 | 1000 | 3 | 1 | |
| 32 | 62 | 0 | 11 | 48 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 15 | 0 | 31 | 0 | 21 | 738 | 1000 | 3 | 1 | |
| 33 | 62 | 0 | 7 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 15 | 0 | 31 | 0 | 21 | 628 | 1000 | 3 | 1 | |
| 34 | 0 | 62 | 104 | 0 | 0 | 96 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 15 | 0 | 31 | 0 | 21 | 639 | 1000 | 3 | 1 | |
| 35 | 0 | 62 | 127 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 15 | 0 | 31 | 0 | 21 | 546 | 1000 | 3 | 1 | |
| | | | | | | | | | | | | | | | 161 | 0 | 0 | 0 | 0 | 0 | 16 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | | | | | | | | | | | | | | | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
|-----|-----|-----|-----|-----|-----|---|---|---|-----|-----|---|----|----|---|----|-----|-----|-----|----|-----|------|------|------|----|-----|------|------|------|---|---|
| 130 | 100 | 0 | 57 | 0 | 0 | 0 | 0 | 0 | 0 | 292 | 0 | 0 | 25 | 0 | 0 | 50 | 0 | 50 | 0 | 67 | 40 | 1000 | 2 | 2 | | | | | | |
| 131 | 0 | 100 | 429 | 0 | 138 | 0 | 0 | 0 | 0 | 152 | 0 | 0 | 25 | 0 | 0 | 50 | 0 | 50 | 0 | 67 | 479 | 1000 | 2 | 2 | | | | | | |
| 132 | 100 | 0 | 96 | 0 | 31 | 0 | 0 | 0 | 0 | 117 | 0 | 0 | 25 | 0 | 0 | 50 | 0 | 50 | 0 | 311 | 1000 | 2 | 2 | | | | | | | |
| 133 | 0 | 100 | 294 | 0 | 103 | 0 | 0 | 0 | 0 | 156 | 0 | 0 | 25 | 0 | 0 | 50 | 0 | 50 | 0 | 67 | 497 | 1000 | 2 | 2 | | | | | | |
| 134 | 100 | 0 | 18 | 138 | 0 | 0 | 0 | 0 | 0 | 156 | 0 | 0 | 25 | 0 | 0 | 50 | 0 | 50 | 0 | 67 | 428 | 1000 | 2 | 2 | | | | | | |
| 135 | 0 | 100 | 6 | 57 | 0 | 0 | 0 | 0 | 0 | 292 | 0 | 0 | 25 | 0 | 0 | 50 | 0 | 50 | 0 | 67 | 621 | 1000 | 2 | 2 | | | | | | |
| 136 | 0 | 100 | 88 | 0 | 0 | 0 | 0 | 0 | 214 | 19 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 579 | 1000 | 2 | 2 | | | | | | |
| 137 | 100 | 0 | 11 | 0 | 0 | 0 | 0 | 0 | 73 | 0 | 0 | 0 | 81 | 0 | 25 | 0 | 50 | 0 | 67 | 593 | 1000 | 2 | 2 | | | | | | | |
| 138 | 0 | 100 | 172 | 0 | 0 | 0 | 0 | 0 | 167 | 0 | 0 | 0 | 15 | 0 | 0 | 0 | 0 | 0 | 0 | 50 | 67 | 429 | 1000 | 2 | 2 | | | | | |
| 139 | 100 | 0 | 24 | 0 | 0 | 0 | 0 | 0 | 216 | 0 | 0 | 19 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 33 | 558 | 1000 | 2 | 2 | | | | | | |
| 140 | 100 | 0 | 11 | 116 | 0 | 0 | 0 | 0 | 0 | 20 | 0 | 0 | 10 | 0 | 0 | 25 | 0 | 0 | 0 | 67 | 621 | 1000 | 2 | 2 | | | | | | |
| 141 | 100 | 0 | 52 | 0 | 43 | 0 | 0 | 0 | 216 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 33 | 480 | 1000 | 2 | 2 | | | | | | |
| 142 | 0 | 100 | 662 | 0 | 216 | 0 | 0 | 0 | 19 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 33 | 81 | 1000 | 2 | 2 | | | | | | |
| 143 | 100 | 0 | 11 | 0 | 0 | 0 | 0 | 0 | 116 | 0 | 0 | 0 | 10 | 0 | 0 | 25 | 0 | 0 | 0 | 67 | 621 | 1000 | 2 | 2 | | | | | | |
| 144 | 100 | 0 | 140 | 0 | 0 | 0 | 0 | 0 | 136 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 33 | 365 | 1000 | 2 | 2 | | | | | | |
| 145 | 0 | 100 | 347 | 0 | 114 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 33 | 345 | 1000 | 2 | 2 | | | | | | |
| 146 | 0 | 100 | 6 | 0 | 0 | 0 | 0 | 0 | 112 | 0 | 0 | 0 | 0 | 0 | 0 | 25 | 0 | 0 | 0 | 50 | 0 | 697 | 1000 | 2 | 2 | | | | | |
| 147 | 100 | 0 | 5 | 0 | 0 | 0 | 0 | 0 | 138 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 67 | 488 | 1000 | 2 | 2 | | | | | |
| 148 | 0 | 100 | 49 | 0 | 0 | 0 | 0 | 0 | 30 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 675 | 1000 | 2 | 2 | | | | | | |
| 149 | 0 | 100 | 129 | 0 | 0 | 0 | 0 | 0 | 116 | 0 | 0 | 0 | 0 | 0 | 0 | 10 | 0 | 0 | 0 | 0 | 67 | 553 | 1000 | 2 | 2 | | | | | |
| 150 | 100 | 0 | 60 | 0 | 43 | 0 | 0 | 0 | 43 | 0 | 0 | 0 | 0 | 0 | 0 | 219 | 0 | 0 | 0 | 50 | 0 | 526 | 1000 | 2 | 2 | | | | | |
| 151 | 0 | 62 | 51 | 0 | 0 | 0 | 0 | 0 | 48 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 238 | 0 | 0 | 0 | 15 | 0 | 31 | 21 | 534 | 1000 | 3 | 1 | | |
| 152 | 62 | 0 | 4 | 0 | 0 | 0 | 0 | 0 | 40 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 202 | 0 | 0 | 0 | 0 | 0 | 31 | 21 | 642 | 1000 | 3 | 1 | | |
| 153 | 62 | 0 | 3 | 0 | 0 | 0 | 0 | 0 | 118 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 10 | 0 | 0 | 0 | 31 | 0 | 0 | 0 | 776 | 1000 | 3 | 1 | | |
| 154 | 0 | 62 | 191 | 0 | 0 | 0 | 0 | 0 | 183 | 0 | 0 | 0 | 0 | 0 | 0 | 16 | 0 | 0 | 0 | 15 | 0 | 0 | 0 | 41 | 492 | 1000 | 3 | 1 | | |
| 155 | 62 | 0 | 7 | 0 | 0 | 0 | 0 | 0 | 116 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 131 | 0 | 0 | 0 | 0 | 0 | 31 | 0 | 41 | 613 | 1000 | 3 | 1 | |
| 156 | 0 | 62 | 12 | 0 | 0 | 0 | 0 | 0 | 40 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 197 | 0 | 0 | 0 | 0 | 0 | 15 | 0 | 31 | 0 | 689 | 1000 | 3 | 1 |
| 157 | 62 | 0 | 11 | 151 | 0 | 0 | 0 | 0 | 0 | 48 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 245 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 41 | 600 | 1000 | 3 | 1 |
| 158 | 0 | 62 | 12 | 0 | 0 | 0 | 0 | 0 | 121 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 11 | 0 | 0 | 0 | 0 | 0 | 13 | 0 | 31 | 0 | 728 | 1000 | 3 | 1 |
| 159 | 0 | 62 | 361 | 0 | 121 | 0 | 0 | 0 | 0 | 116 | 0 | 0 | 0 | 0 | 0 | 0 | 84 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 31 | 41 | 708 | 1000 | 3 | 1 |
| 160 | 62 | 0 | 7 | 0 | 0 | 0 | 0 | 0 | 181 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 181 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 31 | 41 | 359 | 1000 | 3 | 1 |
| 161 | 0 | 62 | 4 | 0 | 0 | 0 | 0 | 0 | 48 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 48 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 31 | 41 | 632 | 1000 | 3 | 1 |
| 162 | 0 | 62 | 236 | 0 | 75 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 83 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 31 | 41 | 478 | 1000 | 3 | 1 |
| 163 | 62 | 0 | 202 | 0 | 75 | 0 | 0 | 0 | 0 | 84 | 0 | 0 | 0 | 0 | 0 | 0 | 15 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 31 | 41 | 492 | 1000 | 3 | 1 |
| 164 | 0 | 62 | 12 | 116 | 0 | 0 | 0 | 0 | 0 | 131 | 0 | 0 | 0 | 0 | 0 | 0 | 16 | 0 | 0 | 0 | 15 | 0 | 0 | 0 | 31 | 41 | 624 | 1000 | 3 | 1 |
| 165 | 0 | 62 | 101 | 0 | 32 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 158 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 31 | 41 | 576 | 1000 | 3 | 1 |
| 166 | 62 | 0 | 16 | 0 | 0 | 0 | 0 | 0 | 31 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 156 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 31 | 41 | 714 | 1000 | 3 | 1 |
| 167 | 0 | 62 | 4 | 114 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 125 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 31 | 41 | 665 | 1000 | 3 | 1 |
| 168 | 0 | 62 | 123 | 0 | 0 | 0 | 0 | 0 | 116 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 128 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 31 | 41 | 515 | 1000 | 3 | 1 |
| 169 | 62 | 0 | 11 | 31 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 158 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 31 | 41 | 692 | 1000 | 3 | 1 |
| 170 | 0 | 62 | 12 | 0 | 0 | 0 | 0 | 0 | 94 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 104 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 31 | 41 | 683 | 1000 | 3 | 1 |
| 171 | 0 | 62 | 12 | 95 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 105 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 31 | 41 | 660 | 1000 | 3 | 1 |
| 172 | 0 | 62 | 12 | 0 | 0 | 0 | 0 | 0 | 75 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 83 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 31 | 41 | 770 | 1000 | 3 | 1 |
| 173 | 0 | 62 | 55 | 0 | 0 | 0 | 0 | 0 | 48 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 242 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 31 | 41 | 548 | 1000 | 3 | 1 |
| 174 | 0 | 62 | 357 | 0 | 119 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 11 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 31 | 41 | 1000 | 3 | 1 | |
| 175 | 0 | 62 | 8 | 119 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 11 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 31 | 41 | 734 | 1000 | 3 | 1 |
| 176 | 62 | 0 | 104 | 0 | 48 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 31 | 41 | 520 | 1000 | 3 | 1 |

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|-----|-----|-----|-----|-----|-----|-----|---|-----|-----|-----|-----|-----|----|-----|------|------|------|------|------|------|------|------|---|---|
| 224 | 73 | 0 | 10 | 0 | 0 | 29 | 0 | 0 | 145 | 0 | 0 | 0 | 0 | 744 | 1000 | 3 | 1 | | | | | | | |
| 225 | 0 | 73 | 462 | 0 | 151 | 0 | 0 | 0 | 13 | 0 | 0 | 36 | 0 | 48 | 216 | 1000 | 3 | 1 | | | | | | |
| 226 | 73 | 0 | 197 | 0 | 72 | 0 | 0 | 0 | 0 | 79 | 0 | 0 | 18 | 0 | 0 | 514 | 1000 | 3 | 1 | | | | | |
| 227 | 0 | 73 | 549 | 0 | 185 | 0 | 0 | 0 | 16 | 0 | 0 | 0 | 0 | 0 | 36 | 0 | 141 | 1000 | 3 | 1 | | | | |
| 228 | 0 | 73 | 9 | 0 | 0 | 0 | 0 | 0 | 16 | 0 | 0 | 18 | 0 | 36 | 0 | 663 | 1000 | 3 | 1 | | | | | |
| 229 | 0 | 73 | 446 | 0 | 149 | 0 | 0 | 0 | 0 | 13 | 0 | 0 | 36 | 0 | 24 | 259 | 1000 | 3 | 1 | | | | | |
| 230 | 0 | 73 | 19 | 0 | 0 | 0 | 0 | 39 | 0 | 0 | 0 | 0 | 36 | 0 | 24 | 608 | 1000 | 3 | 1 | | | | | |
| 231 | 73 | 0 | 112 | 0 | 39 | 0 | 0 | 0 | 198 | 0 | 0 | 18 | 0 | 0 | 0 | 0 | 150 | 1000 | 3 | 1 | | | | |
| 232 | 0 | 73 | 189 | 0 | 0 | 186 | 0 | 0 | 17 | 0 | 0 | 0 | 0 | 18 | 0 | 36 | 24 | 456 | 1000 | 3 | 1 | | | |
| 233 | 0 | 73 | 124 | 0 | 0 | 111 | 0 | 0 | 10 | 0 | 0 | 0 | 0 | 18 | 0 | 0 | 0 | 664 | 1000 | 3 | 1 | | | |
| 234 | 73 | 0 | 43 | 0 | 0 | 0 | 0 | 186 | 0 | 16 | 0 | 0 | 0 | 36 | 0 | 24 | 621 | 1000 | 3 | 1 | | | | |
| 235 | 73 | 0 | 311 | 0 | 117 | 0 | 0 | 0 | 132 | 0 | 0 | 0 | 0 | 18 | 0 | 0 | 0 | 313 | 1000 | 3 | 1 | | | |
| 236 | 0 | 73 | 100 | 0 | 29 | 0 | 0 | 0 | 0 | 0 | 0 | 144 | 0 | 18 | 0 | 0 | 0 | 636 | 1000 | 3 | 1 | | | |
| 237 | 0 | 73 | 9 | 0 | 0 | 93 | 0 | 0 | 0 | 0 | 102 | 0 | 0 | 18 | 0 | 36 | 0 | 0 | 668 | 1000 | 3 | 1 | | |
| 238 | 0 | 73 | 202 | 0 | 93 | 0 | 0 | 0 | 103 | 0 | 0 | 0 | 0 | 18 | 0 | 0 | 0 | 431 | 1000 | 3 | 1 | | | |
| 239 | 73 | 0 | 66 | 0 | 30 | 0 | 0 | 0 | 0 | 146 | 0 | 0 | 18 | 0 | 0 | 24 | 644 | 1000 | 3 | 1 | | | | |
| 240 | 0 | 73 | 140 | 0 | 49 | 0 | 0 | 0 | 0 | 242 | 0 | 0 | 0 | 0 | 36 | 0 | 24 | 460 | 1000 | 3 | 1 | | | |
| 241 | 0 | 73 | 4 | 71 | 0 | 0 | 0 | 0 | 0 | 0 | 78 | 0 | 0 | 0 | 0 | 24 | 732 | 1000 | 3 | 1 | | | | |
| 242 | 0 | 73 | 94 | 0 | 0 | 0 | 0 | 93 | 0 | 103 | 0 | 0 | 0 | 0 | 36 | 0 | 0 | 600 | 1000 | 3 | 1 | | | |
| 243 | 0 | 73 | 23 | 0 | 0 | 0 | 0 | 49 | 0 | 0 | 240 | 0 | 0 | 0 | 0 | 0 | 0 | 616 | 1000 | 3 | 1 | | | |
| 244 | 73 | 0 | 232 | 0 | 116 | 0 | 0 | 0 | 0 | 0 | 129 | 0 | 0 | 18 | 0 | 3 | 0 | 24 | 386 | 1000 | 3 | 1 | | |
| 245 | 73 | 0 | 46 | 0 | 0 | 40 | 0 | 0 | 0 | 197 | 0 | 0 | 0 | 0 | 18 | 0 | 36 | 0 | 48 | 542 | 1000 | 3 | 1 | |
| 246 | 73 | 0 | 28 | 0 | 0 | 0 | 0 | 93 | 0 | 0 | 102 | 0 | 0 | 0 | 0 | 0 | 0 | 704 | 1000 | 3 | 1 | | | |
| 247 | 0 | 73 | 29 | 0 | 0 | 0 | 0 | 30 | 0 | 0 | 149 | 0 | 0 | 0 | 0 | 0 | 0 | 48 | 671 | 1000 | 3 | 1 | | |
| 248 | 0 | 73 | 74 | 0 | 0 | 70 | 0 | 0 | 0 | 79 | 0 | 0 | 18 | 0 | 36 | 0 | 0 | 650 | 1000 | 3 | 1 | | | |
| 249 | 73 | 0 | 4 | 0 | 0 | 118 | 0 | 0 | 0 | 0 | 129 | 0 | 0 | 18 | 0 | 0 | 0 | 596 | 1000 | 3 | 1 | | | |
| 250 | 0 | 73 | 74 | 0 | 0 | 70 | 0 | 0 | 77 | 0 | 0 | 0 | 0 | 18 | 0 | 0 | 0 | 652 | 1000 | 3 | 1 | | | |
| 251 | 100 | 0 | 120 | 0 | 0 | 104 | 0 | 0 | 118 | 0 | 0 | 0 | 0 | 0 | 50 | 0 | 33 | 474 | 1000 | 3 | 1 | | | |
| 252 | 100 | 0 | 11 | 0 | 0 | 116 | 0 | 0 | 0 | 0 | 10 | 0 | 0 | 0 | 0 | 0 | 67 | 696 | 1000 | 2 | 2 | | | |
| 253 | 100 | 0 | 11 | 112 | 0 | 0 | 0 | 0 | 0 | 0 | 114 | 0 | 0 | 0 | 0 | 0 | 50 | 0 | 717 | 1000 | 2 | 2 | | |
| 254 | 100 | 0 | 119 | 0 | 103 | 0 | 0 | 0 | 0 | 0 | 290 | 0 | 0 | 25 | 0 | 0 | 50 | 0 | 514 | 1000 | 2 | 2 | | |
| 255 | 100 | 0 | 18 | 0 | 0 | 0 | 0 | 57 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 33 | 477 | 1000 | 2 | 2 | | | |
| 256 | 100 | 0 | 5 | 0 | 0 | 0 | 0 | 112 | 0 | 0 | 0 | 0 | 0 | 10 | 0 | 0 | 0 | 50 | 0 | 723 | 1000 | 2 | 2 | |
| 257 | 0 | 100 | 6 | 0 | 0 | 214 | 0 | 0 | 0 | 19 | 0 | 0 | 25 | 0 | 0 | 0 | 0 | 67 | 696 | 1000 | 2 | 2 | | |
| 258 | 100 | 0 | 5 | 73 | 0 | 0 | 0 | 0 | 81 | 0 | 0 | 0 | 0 | 25 | 0 | 0 | 0 | 565 | 1000 | 2 | 2 | | | |
| 259 | 100 | 0 | 5 | 0 | 0 | 57 | 0 | 0 | 0 | 0 | 283 | 0 | 0 | 0 | 0 | 0 | 50 | 0 | 67 | 599 | 1000 | 2 | 2 | |
| 260 | 100 | 0 | 14 | 0 | 0 | 0 | 0 | 44 | 0 | 219 | 0 | 0 | 0 | 0 | 10 | 0 | 25 | 0 | 0 | 33 | 497 | 1000 | 2 | 2 |
| 261 | 0 | 100 | 135 | 0 | 0 | 0 | 0 | 135 | 0 | 0 | 0 | 0 | 0 | 147 | 0 | 0 | 0 | 50 | 0 | 67 | 557 | 1000 | 2 | 2 |
| 262 | 100 | 0 | 11 | 0 | 0 | 114 | 0 | 0 | 0 | 10 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 50 | 0 | 0 | 427 | 1000 | 2 | 2 |
| 263 | 100 | 0 | 19 | 0 | 0 | 138 | 0 | 0 | 0 | 0 | 152 | 0 | 0 | 0 | 0 | 0 | 50 | 0 | 33 | 681 | 1000 | 2 | 2 | |
| 264 | 100 | 0 | 11 | 0 | 0 | 112 | 0 | 0 | 0 | 0 | 10 | 0 | 0 | 25 | 0 | 0 | 50 | 0 | 67 | 474 | 1000 | 2 | 2 | |
| 265 | 100 | 0 | 39 | 0 | 0 | 30 | 0 | 0 | 0 | 0 | 147 | 0 | 0 | 25 | 0 | 0 | 50 | 0 | 692 | 1000 | 2 | 2 | | |
| 266 | 0 | 100 | 12 | 114 | 0 | 0 | 0 | 0 | 10 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 608 | 1000 | 2 | 2 | | | |
| 267 | 100 | 0 | 11 | 30 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 25 | 0 | 0 | 50 | 0 | 33 | 655 | 1000 | 2 | 2 | |
| 268 | 0 | 100 | 91 | 0 | 0 | 72 | 0 | 0 | 0 | 0 | 150 | 0 | 0 | 25 | 0 | 0 | 50 | 0 | 634 | 1000 | 2 | 2 | | |
| 269 | 100 | 0 | 61 | 0 | 0 | 43 | 0 | 0 | 0 | 0 | 82 | 0 | 0 | 0 | 0 | 0 | 50 | 0 | 33 | 572 | 1000 | 2 | 2 | |
| 270 | 100 | 0 | 140 | 0 | 0 | 56 | 0 | 0 | 0 | 0 | 216 | 0 | 0 | 0 | 0 | 0 | 33 | 546 | 1000 | 2 | 2 | | | |

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|-----|----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|----|-----|-----|------|------|------|------|------|------|---|---|
| 316 | 62 | 0 | 206 | 0 | 76 | 0 | 0 | 0 | 0 | 86 | 0 | 0 | 15 | 0 | 31 | 0 | 41 | 483 | 1000 | 3 | 1 | | | | |
| 319 | 0 | 62 | 8 | 0 | 0 | 0 | 121 | 0 | 11 | 0 | 0 | 0 | 15 | 0 | 31 | 41 | 712 | 1000 | 3 | 1 | | | | | |
| 320 | 62 | 0 | 11 | 118 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 15 | 0 | 31 | 0 | 0 | 753 | 1000 | 3 | 1 | | | | |
| 321 | 62 | 0 | 98 | 0 | 40 | 0 | 0 | 0 | 0 | 199 | 0 | 0 | 0 | 0 | 0 | 0 | 41 | 545 | 1000 | 3 | 1 | | | | |
| 322 | 62 | 0 | 30 | 0 | 0 | 0 | 0 | 119 | 0 | 0 | 0 | 0 | 10 | 0 | 0 | 31 | 0 | 21 | 727 | 1000 | 3 | 1 | | | |
| 323 | 0 | 62 | 110 | 0 | 0 | 0 | 0 | 114 | 0 | 0 | 129 | 0 | 0 | 0 | 0 | 31 | 0 | 0 | 554 | 1000 | 3 | 1 | | | |
| 324 | 0 | 62 | 12 | 31 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 155 | 15 | 0 | 31 | 0 | 0 | 695 | 1000 | 3 | 1 | | | |
| 325 | 62 | 0 | 7 | 0 | 0 | 0 | 0 | 114 | 0 | 0 | 0 | 129 | 0 | 0 | 0 | 0 | 0 | 673 | 1000 | 3 | 1 | | | | |
| 326 | 0 | 62 | 43 | 0 | 0 | 0 | 31 | 0 | 0 | 0 | 0 | 155 | 0 | 0 | 15 | 31 | 0 | 21 | 642 | 1000 | 3 | 1 | | | |
| 327 | 62 | 0 | 11 | 48 | 0 | 0 | 0 | 0 | 244 | 0 | 0 | 0 | 0 | 0 | 0 | 31 | 21 | 585 | 1000 | 3 | 1 | | | | |
| 328 | 0 | 62 | 4 | 0 | 0 | 0 | 181 | 0 | 16 | 0 | 0 | 0 | 0 | 0 | 0 | 31 | 0 | 0 | 707 | 1000 | 3 | 1 | | | |
| 329 | 0 | 62 | 28 | 0 | 0 | 0 | 0 | 0 | 31 | 0 | 165 | 0 | 0 | 0 | 0 | 31 | 0 | 0 | 694 | 1000 | 3 | 1 | | | |
| 330 | 0 | 62 | 106 | 0 | 32 | 0 | 0 | 0 | 0 | 0 | 158 | 0 | 0 | 0 | 15 | 0 | 31 | 41 | 555 | 1000 | 3 | 1 | | | |
| 331 | 62 | 0 | 3 | 119 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 10 | 0 | 15 | 0 | 31 | 21 | 739 | 1000 | 3 | 1 | | | |
| 332 | 62 | 0 | 301 | 0 | 152 | 0 | 0 | 0 | 0 | 14 | 0 | 0 | 0 | 0 | 0 | 15 | 0 | 31 | 41 | 385 | 1000 | 3 | 1 | | |
| 333 | 0 | 62 | 12 | 31 | 0 | 0 | 0 | 0 | 0 | 0 | 160 | 0 | 0 | 0 | 0 | 0 | 0 | 21 | 715 | 1000 | 3 | 1 | | | |
| 334 | 62 | 0 | 5 | 0 | 0 | 0 | 0 | 118 | 0 | 0 | 0 | 0 | 10 | 0 | 0 | 0 | 31 | 0 | 0 | 774 | 1000 | 3 | 1 | | |
| 335 | 0 | 62 | 87 | 0 | 0 | 75 | 0 | 0 | 85 | 0 | 0 | 0 | 0 | 0 | 0 | 31 | 0 | 21 | 639 | 1000 | 3 | 1 | | | |
| 336 | 62 | 0 | 116 | 0 | 0 | 116 | 0 | 0 | 0 | 0 | 127 | 0 | 0 | 0 | 15 | 0 | 31 | 41 | 492 | 1000 | 3 | 1 | | | |
| 337 | 62 | 0 | 30 | 0 | 0 | 0 | 0 | 119 | 0 | 0 | 0 | 0 | 10 | 0 | 0 | 0 | 31 | 21 | 727 | 1000 | 3 | 1 | | | |
| 338 | 0 | 62 | 74 | 0 | 0 | 0 | 0 | 183 | 0 | 0 | 16 | 0 | 0 | 0 | 0 | 0 | 31 | 41 | 593 | 1000 | 3 | 1 | | | |
| 339 | 62 | 0 | 11 | 182 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 16 | 0 | 15 | 31 | 0 | 21 | 663 | 1000 | 3 | 1 | | | |
| 340 | 0 | 62 | 39 | 0 | 0 | 32 | 0 | 0 | 0 | 0 | 0 | 0 | 158 | 0 | 15 | 0 | 31 | 41 | 622 | 1000 | 3 | 1 | | | |
| 341 | 62 | 0 | 14 | 0 | 0 | 0 | 116 | 0 | 0 | 0 | 127 | 0 | 0 | 0 | 0 | 0 | 41 | 641 | 1000 | 3 | 1 | | | | |
| 342 | 0 | 62 | 189 | 0 | 0 | 162 | 0 | 0 | 0 | 0 | 16 | 0 | 0 | 0 | 0 | 0 | 21 | 531 | 1000 | 3 | 1 | | | | |
| 343 | 0 | 62 | 8 | 48 | 0 | 0 | 0 | 0 | 240 | 0 | 0 | 0 | 0 | 15 | 0 | 0 | 0 | 41 | 586 | 1000 | 3 | 1 | | | |
| 344 | 62 | 0 | 9 | 0 | 0 | 0 | 40 | 0 | 189 | 0 | 0 | 0 | 0 | 0 | 0 | 31 | 41 | 618 | 1000 | 3 | 1 | | | | |
| 345 | 62 | 0 | 3 | 116 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 128 | 0 | 15 | 0 | 31 | 41 | 604 | 1000 | 3 | 1 | | | |
| 346 | 62 | 0 | 68 | 0 | 76 | 0 | 0 | 0 | 0 | 84 | 0 | 0 | 0 | 15 | 0 | 31 | 41 | 624 | 1000 | 3 | 1 | | | | |
| 347 | 0 | 62 | 4 | 0 | 0 | 0 | 31 | 0 | 0 | 156 | 0 | 0 | 0 | 15 | 0 | 31 | 0 | 21 | 680 | 1000 | 3 | 1 | | | |
| 348 | 0 | 62 | 22 | 0 | 0 | 0 | 48 | 0 | 0 | 237 | 0 | 0 | 0 | 0 | 0 | 31 | 0 | 21 | 581 | 1000 | 3 | 1 | | | |
| 349 | 62 | 0 | 7 | 96 | 0 | 0 | 0 | 0 | 0 | 0 | 106 | 0 | 0 | 0 | 0 | 31 | 41 | 656 | 1000 | 3 | 1 | | | | |
| 350 | 62 | 168 | 0 | 0 | 0 | 162 | 0 | 0 | 0 | 0 | 128 | 0 | 0 | 0 | 15 | 0 | 31 | 41 | 604 | 1000 | 3 | 1 | | | |
| 351 | 0 | 73 | 9 | 0 | 0 | 70 | 0 | 79 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 31 | 41 | 521 | 1000 | 3 | 1 | | | | |
| 352 | 73 | 0 | 129 | 0 | 0 | 148 | 0 | 0 | 0 | 0 | 13 | 0 | 0 | 0 | 0 | 36 | 0 | 0 | 769 | 1000 | 3 | 1 | | | |
| 353 | 73 | 0 | 184 | 0 | 0 | 186 | 0 | 0 | 0 | 0 | 0 | 0 | 16 | 0 | 18 | 36 | 0 | 24 | 684 | 1000 | 3 | 1 | | | |
| 354 | 73 | 0 | 296 | 0 | 149 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 13 | 0 | 0 | 18 | 0 | 0 | 391 | 1000 | 3 | 1 | | | |
| 355 | 0 | 73 | 222 | 0 | 70 | 0 | 0 | 0 | 0 | 79 | 0 | 0 | 0 | 0 | 0 | 31 | 21 | 557 | 1000 | 3 | 1 | | | | |
| 356 | 0 | 73 | 109 | 0 | 95 | 0 | 0 | 0 | 0 | 105 | 0 | 0 | 0 | 0 | 0 | 36 | 0 | 0 | 48 | 551 | 1000 | 3 | 1 | | |
| 357 | 0 | 73 | 14 | 71 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 36 | 0 | 24 | 684 | 1000 | 3 | 1 | | | |
| 358 | 73 | 0 | 86 | 0 | 39 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 193 | 0 | 18 | 0 | 0 | 0 | 0 | 0 | | |
| 359 | 73 | 0 | 13 | 0 | 0 | 0 | 29 | 0 | 0 | 0 | 0 | 0 | 0 | 144 | 0 | 18 | 0 | 0 | 36 | 0 | 0 | 687 | 1000 | 3 | 1 |
| 360 | 0 | 73 | 158 | 0 | 149 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 13 | 0 | 0 | 24 | 564 | 1000 | 3 | 1 | | |
| 361 | 73 | 0 | 172 | 0 | 72 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 79 | 0 | 0 | 48 | 502 | 1000 | 3 | 1 | | |
| 362 | 73 | 0 | 205 | 0 | 95 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 105 | 18 | 0 | 0 | 48 | 456 | 1000 | 3 | 1 | |
| 363 | 73 | 0 | 4 | 0 | 0 | 49 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 242 | 0 | 18 | 0 | 0 | 615 | 1000 | 3 | 1 | |
| 364 | 0 | 73 | 71 | 0 | 0 | 0 | 94 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 104 | 0 | 0 | 36 | 24 | 597 | 1000 | 3 | 1 | |

We claim:

1. A method for forming dyed protein crystals comprising:
 - (a) providing a protein solution, wherein the protein solution contains at least one dye, which dye is capable of dyeing at least a portion of protein crystals formed from the protein solution;
 - (b) subjecting the protein solution to environmental conditions effective to form protein crystals; and
 - (c) detecting the presence of dyed protein crystals, whereby the presence of the dyed protein crystals indicates the presence of protein crystals.
2. The method of claim 1, wherein the dye is selected from the group consisting of methylene blue, methylene green, Izit and crystal violet.
3. The method of claim 1, wherein the dye binds to protein molecules of the protein crystals formed from the protein solution.
4. The method of claim 1, wherein the dye does not bind to protein molecules of the protein crystals formed from the protein solution and wherein molecules of the dye reside in channels present in the protein crystals.
5. The method of claim 1, wherein the protein solution is partitioned from the atmosphere.
6. The method of claim 5, wherein the protein solution is overlayed with an oil selected from the group consisting of paraffin oil, silicone oil and combinations thereof.
7. The method of claim 1, wherein the protein solution further comprises a component selected from the group consisting of salts, buffers, precipitants, crystallization aids and any combination thereof.

8. The method of claim 7, wherein the component crystallizes under the environmental conditions of (b).
9. The method of claim 8, wherein step (b) comprises addition of a precipitate solution.
10. The method of claim 8, wherein the component crystals are undyed component crystals.
11. The method of claim 8, further comprising detecting crystals formed in the provided protein solution and distinguishing dyed protein crystals from undyed component crystals.
12. The method of claim 11, wherein the protein crystals and the component crystals are detected by microscopy.
13. A method for screening protein crystal growth conditions, comprising:
 - (a) providing a set of at least two protein solutions, wherein the protein solutions contain a dye, which dye (i) is capable of dyeing at least a portion of protein crystals formed from the protein solution and (ii) does not dye a significant portion of component crystals formed from the protein solution;
 - (b) subjecting the protein solutions to predetermined conditions, wherein the environmental conditions to which each member of the set of protein solutions is subjected is not identical to the environmental conditions to which another member of the set is subjected; and
 - (c) detecting the presence or non-presence of dyed protein crystals and/or undyed component crystals, wherein:
 - (i) the presence of the dyed protein crystals indicates the formation of protein crystals; and

- (ii) the presence of undyed component crystals indicates formation of component crystals.
14. The method of 13, wherein the set of protein solutions consists of greater than 10 protein solutions.
15. The method of 14, wherein the set of protein solutions consists of greater than 100 protein solutions.
16. The method of claim 13, wherein the dye is selected from the group consisting of methylene blue, methylene green, Izit and crystal violet.
17. The method of claim 13, wherein the protein solutions are partitioned from the atmosphere.
18. The method of claim 17, wherein the protein solutions are overlayed with an oil selected from the group consisting of paraffin oil, silicone oil and combinations thereof.
19. The method of claim 13, wherein the protein solution further comprises a component selected from the group consisting of salt, buffer, precipitant, crystallization aid and any combination thereof.
20. The method of claim 13, wherein the component crystallizes under the environmental conditions of (b).
21. The method of claim 20, wherein step (b) comprises addition of a precipitate solution.

22. The method of claim 20, wherein the component crystals comprise undyed component crystals.
23. The method of claim 22, further comprising distinguishing dyed protein crystals from undyed component crystals.
24. The method of claim 23, wherein dyed protein crystals are distinguished from component crystals by use of microscopy.
25. The method of claim 13, wherein detection of dyed protein crystals indicates a combination of conditions to promote crystal growth of a protein in the provided protein solution.
26. The method of claim 25, wherein the detected dyed protein crystals are evaluated in respect to protein crystal quality.
27. The method of claim 26, wherein the evaluation of protein crystal quality includes criterion selected from the group consisting of size of crystals, volume of crystals, intensity of coloration of crystals by dye, color of coloration of crystals by dye, sharpness of crystal edges, crystal shape and combinations thereof.
28. A method for forming dyed component crystals comprising
 - (a) providing a component solution, wherein the component solution contains at least one dye, which dye is capable of dyeing at least a portion of component crystals formed from the component solution;
 - (b) subjecting the component solution to environmental conditions effective to form component crystals; and
 - (c) detecting the presence of dyed component crystals, whereby the presence of the dyed component crystals indicates the presence of component crystals.

29. The method of claim 28, wherein the component solution is partitioned from the atmosphere.
30. The method of claim 29, wherein the component solution is overlayed with an oil selected from the group consisting of paraffin oil, silicone oil and combinations thereof.
31. The method of claim 28, wherein the component solution further comprises a protein.
32. The method of claim 29, wherein the protein crystallizes under the environmental conditions of (b).
33. The method of claim 32, wherein step (b) comprises addition of a precipitate solution.
34. The method of claim 32, wherein the protein crystals comprises undyed protein crystals.
35. The method of claim 32, further comprising detecting any crystals formed in the provided component solution and distinguishing the undyed protein crystals from the dyed component crystals on the basis that the component crystals are dyed component crystals and the protein crystals are undyed protein crystals.
36. The method of claim 35, wherein the protein crystals and the component crystals are detected by microscopy.
37. A method for screening protein crystal growth conditions, comprising:

- (a) providing a set of at least two protein solutions, wherein the protein solutions contain a dye, which dye (i) is capable of dyeing at least a portion of component crystal formed from the protein solution and (ii) does not dye a significant portion of protein crystals formed from the protein solution;
- (b) subjecting the protein solutions to predetermined conditions, wherein the environmental conditions to which each member of the set of protein solutions is subjected is not identical to the environmental conditions to which another member of the set is subjected; and
- (c) detecting the presence or non-presence of undyed protein crystals and/or dyed component crystals, wherein:
 - (i) the presence of undyed protein crystals indicates the formation of protein crystals; and
 - (ii) the presence of dyed component crystals indicates formation of component crystals.

38. The method of 37, wherein the set of protein solutions consists of greater than 10 protein solutions.

39. The method of 38, wherein the set of protein solutions consists of greater than 100 protein solutions.

40. The method of claim 37, wherein the protein solution is partitioned from the atmosphere.

41. The method of claim 40, wherein the protein solution is overlayed with an oil selected from the group consisting of paraffin oil, silicone oil and combinations thereof.

42. The method of claim 37, wherein the protein solution further comprises a component selected from the group consisting of salt, buffer, precipitant, crystallization aid and any combination thereof.
43. The method of claim 37, wherein the protein crystallizes under the environmental conditions of (b).
44. The method of claim 43, wherein step (b) comprises addition of a precipitate solution.
45. The method of claim 43, wherein the protein crystals comprise undyed protein crystals.
46. The method of claim 45, further comprising distinguishing the undyed protein crystals from the dyed component crystals.
47. The method of claim 46, wherein the undyed protein crystal is distinguished from the component crystals by use of microscopy.
48. The method of claim 37, wherein detection of the undyed protein crystals indicates a combination of conditions to promote crystal growth of a protein in the provided protein solutions.
49. The method of claim 48, wherein the detected undyed protein crystals are evaluated in respect to protein crystal quality.
50. The method of claim 49, wherein the evaluation of protein crystal quality includes criterion selected from the group consisting of size of crystals, volume of crystals,

intensity of coloration of crystals by dye, color of coloration of crystals by dye, sharpness of crystal edges, crystal shape or combinations thereof

51. An automated method of screening protein crystal growth conditions comprising the steps of:

- a) providing a set of at least two protein solutions, wherein the protein solutions contain a dye, which dye (i) is capable of dyeing at least a portion of protein crystals formed from the protein solution and (ii) does not dye a significant portion of component crystals formed from the protein solution;
- b) dispensing the protein solutions onto a platform, wherein the protein solutions are dispensed using an automated dispensing system in accordance with a predetermined program;
- c) controlling the protein crystal growth conditions of the protein solutions; and
- d) detecting the presence or non-presence of dyed protein crystals and/or undyed component crystals, wherein the presence of the dyed protein crystals indicates the formation of protein crystals; and the presence of undyed component crystals indicates the formation of component crystals.

52. The method according to claim 51 wherein protein solutions on the platform are overlayed with an oil.

53. A method for screening protein crystal growth conditions, comprising:

- a) providing a set of at least two protein solutions, wherein the protein solutions contain a dye, which dye (i) is capable of dyeing at least a portion of component crystals formed from the protein solution and (ii) does not dye a significant portion of protein crystals formed from the protein solution;

- b) dispensing the protein solutions onto a platform, wherein the protein solutions are dispensed using an automated dispensing system in accordance with a predetermined program;
 - c) controlling the protein crystal growth conditions of the protein solutions; and
 - d) detecting the presence or non-presence of undyed protein crystals and/or dyed component crystals, wherein the presence of the undyed protein crystals indicates the formation of protein crystals; and the presence of the dyed component crystals indicates formation of component crystals.
54. The method according to claim 53 wherein the protein solutions on the platform are overlayed with an oil.

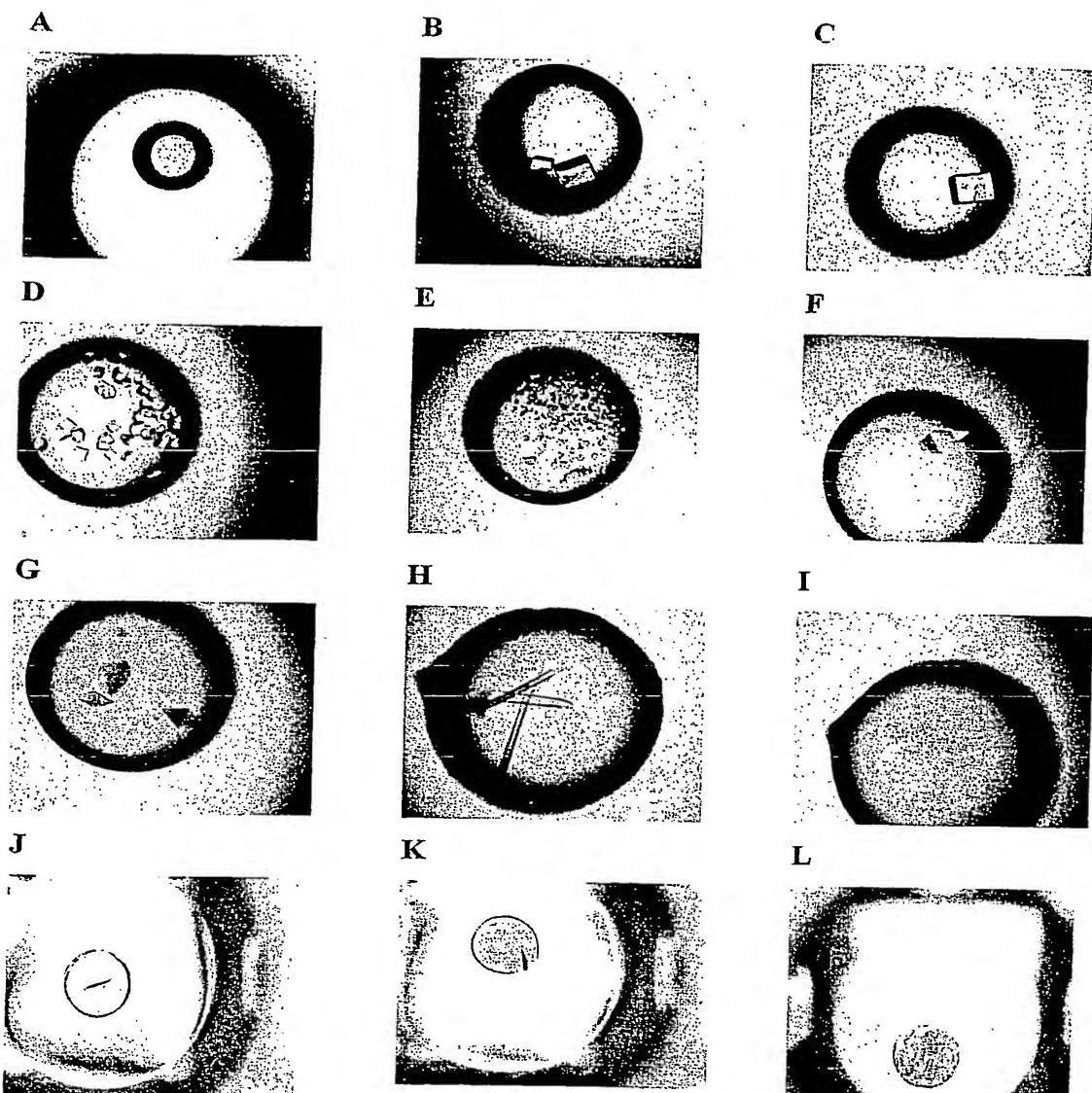


Figure One

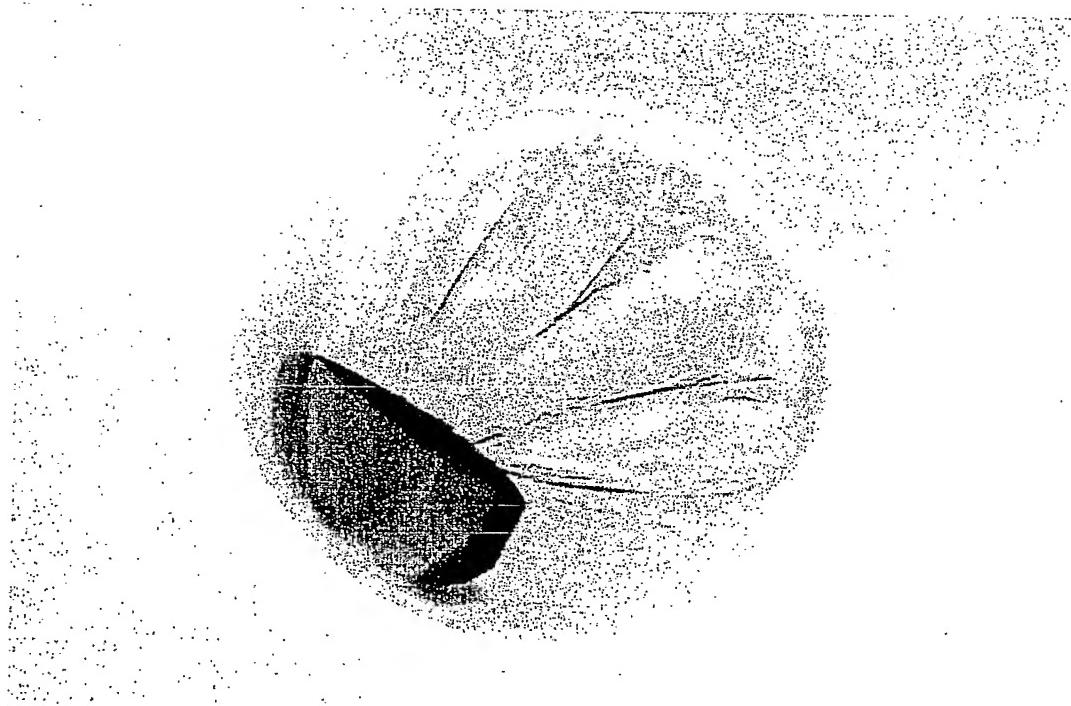


Fig. 2

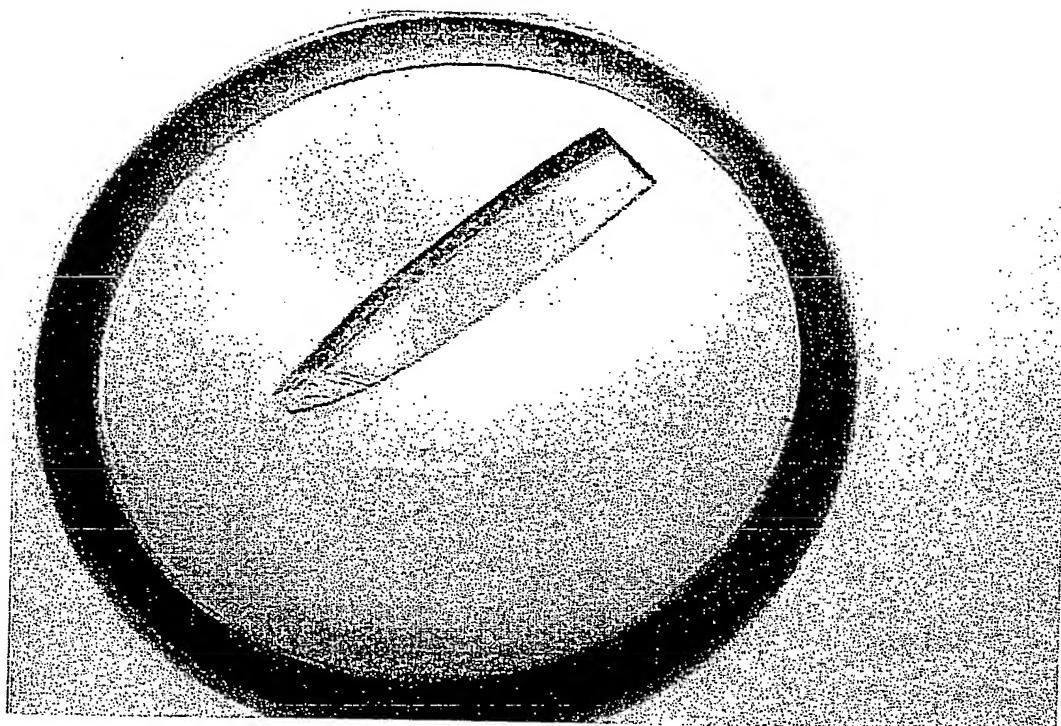


Fig. 3

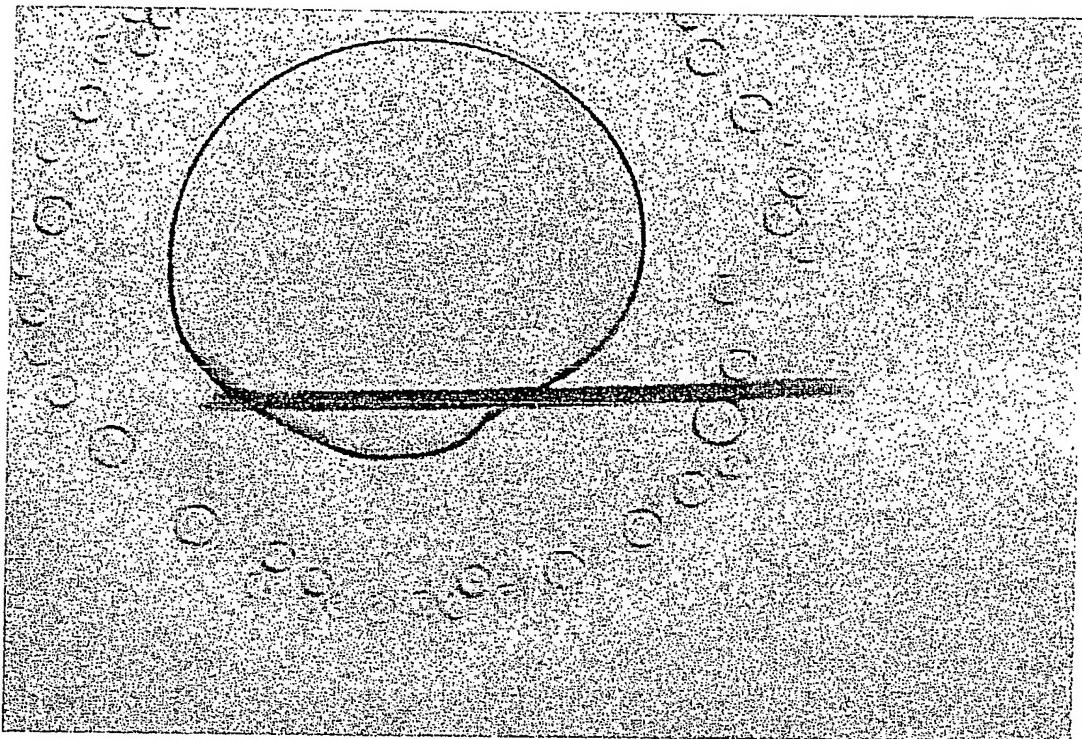


Fig. 4

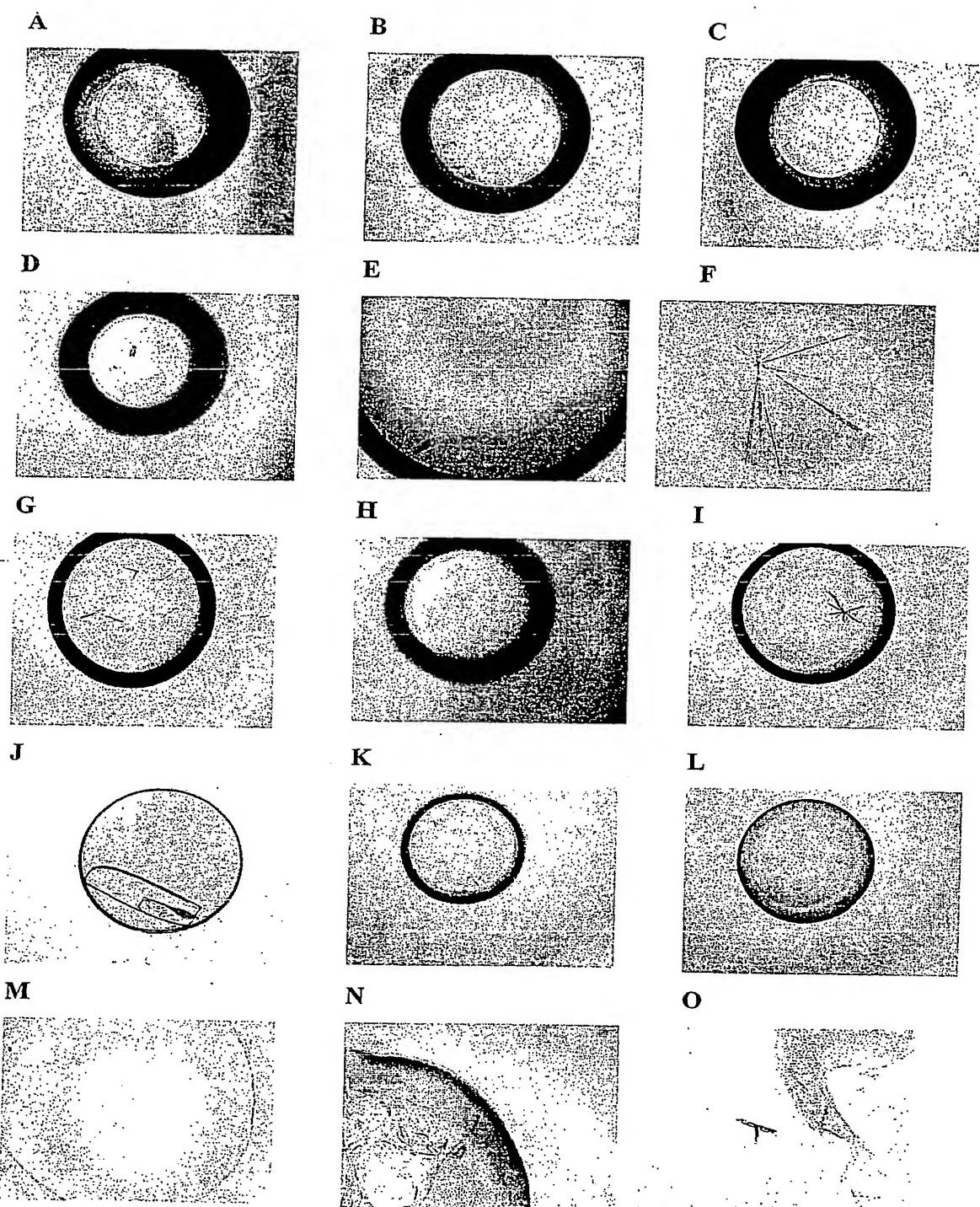


Figure Five

INTERNATIONAL SEARCH REPORT

International application No.

PCT/US02/24032

A. CLASSIFICATION OF SUBJECT MATTER

IPC(7) : G01N 31/00
 US CL : 436/86, 164

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
 U.S. : 436/86, 164

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

| Category * | Citation of document, with indication, where appropriate, of the relevant passages | Relevant to claim No. |
|------------|--|-----------------------|
| A | US 5,013531 A (SNYDER et al) 7 May 1991 (07.05.1991), abstract. | 1-54 |
| A | US 4,517,048 A (SHLICHTA) 14 May 1985 (14.05.1985), abstract. | 1-54 |
| A,E | US 6,468,346 B (ARNOWITZ et al). 22 October 2002 (22.10.2002), abstract. | 1-54 |
| A,P | US 6,406,903 B (BRAY et al) 18 June 2002 (18.06.2002), abstract. | 1-54 |

 Further documents are listed in the continuation of Box C.

See patent family annex.

| | | |
|---|-----|--|
| Special categories of cited documents: | "T" | later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention |
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| "O" document referring to an oral disclosure, use, exhibition or other means | | |
| "P" document published prior to the international filing date but later than the priority date claimed | | |

Date of the actual completion of the international search

Date of mailing of the international search report

03 November 2002 (03.11.2002)

03 DEC 2002

Name and mailing address of the ISA/US

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